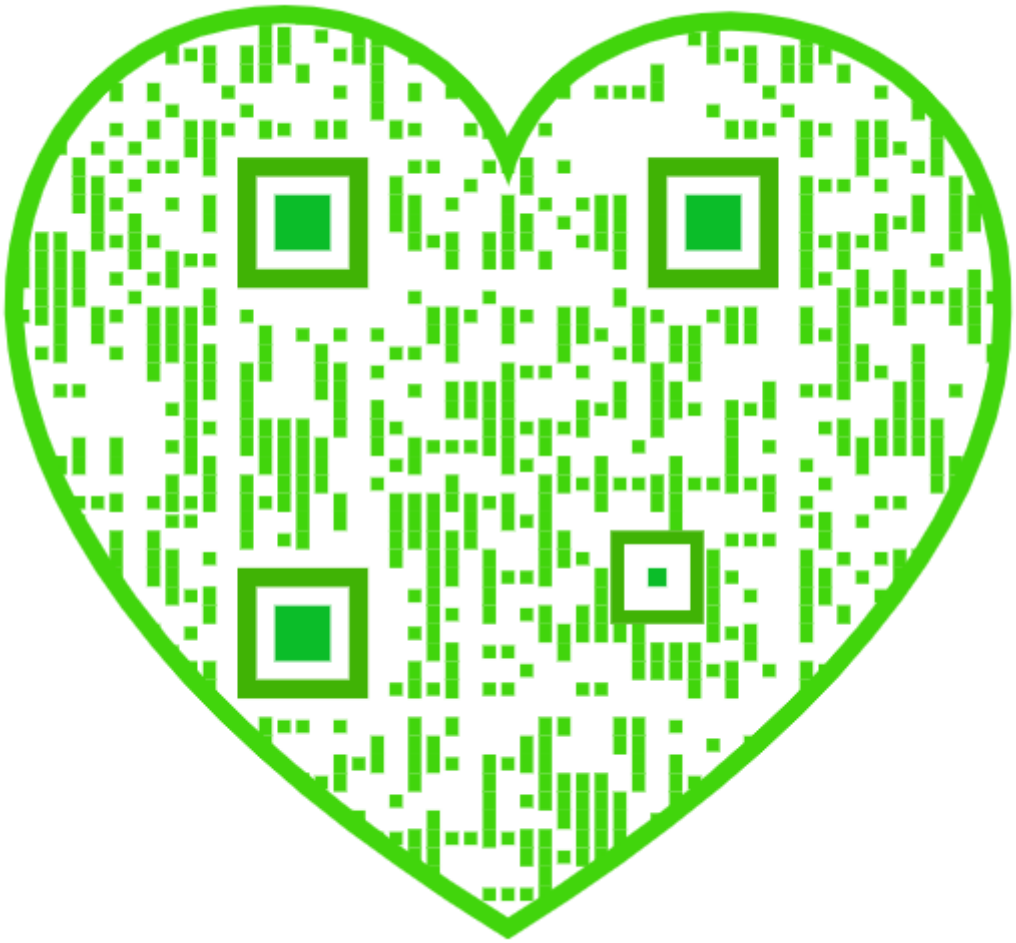

HOW OIL IS USED FOR FUEL ON LOCOMOTIVES.

SUPPLEMENT TO

THE SCIENCE OF RAILWAYS

BY

MARSHALL MONROE KIRKMAN.

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A. Oil Burner—Southern Pacific.....Appendix A

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C General Arrangement of Fittings for Oil Burning Locomotives—Class D. Z. (Ten Wheel Passenger Type)—Southern Pacific .....Appendix A

D. General Arrangement of Oil Tanks to Tender of Oil Burning Locomotives—Southern Pacific.....Appendix A

HOW OIL IS USED FOR FUEL ON LOCOMOTIVES.

WHAT FUEL OIL IS AND HOW OBTAINED.

Fuel oil, as it is commonly called in America, is known to the commerce of the world as Petroleum, a word coined from two latin terms *petra* a rock and *oleum* oil, and which accurately describes the liquid which is found in the earth naturally in many parts of the globe and is believed to be formed by the gradual decomposition of vegetable matter beneath the surface.

The oil varies much in color and consistency in different localities. In some places it is of a faint yellow color thin and almost transparent; in others of a brownish black color sometimes as thick as molasses. It is found in most European countries and in the United States; it has been for many years abundant in Pennsylvania, New York, Ohio and Indiana, and latterly has been found in large quantities in the States of California and Texas.

Generally speaking, the oil is brought to the surface by means of pumping from wells; in some instances, however, the supply is so abundant that the wells have a natural flow; sometimes also it is found oozing from the crevices of rocks or floating on the surface of water.

The existence of petroleum has been known in the states of New York and Pennsylvania from

the earliest Colonial days. It was not till the year 1859, however, that it began to be of commercial importance in America; in that year wells began to be systematically bored. The product of the oil fields of New York and Pennsylvania has been and is, utilized principally as an illuminant, the crude oil being for that purpose refined and marketed in the form of Kerosene. This industry has grown to enormous proportions, not only supplying America with sufficient for home consumption, but exporting a vast quantity annually to all parts of the world.

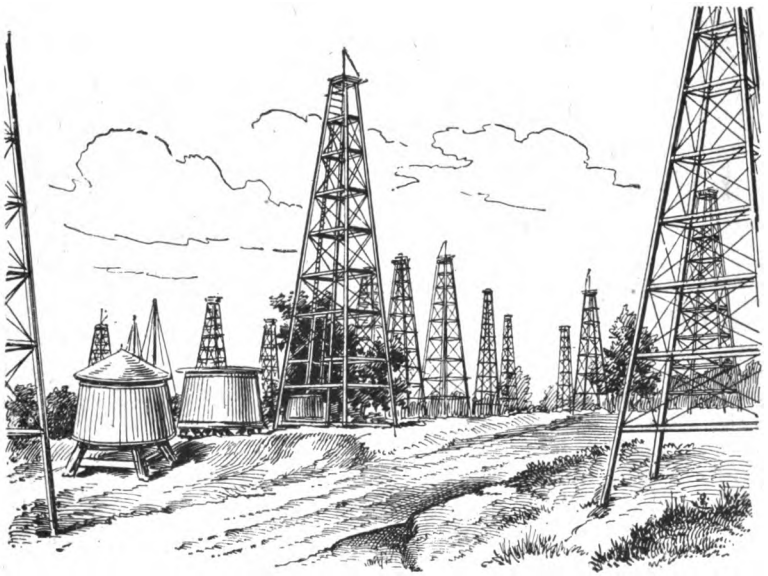


FIG. 1.

OIL FIELDS.

THE USE OF OIL AS FUEL—ITS ADVANTAGES UNDER FAVORABLE CONDITIONS.

The use of oil as fuel is no new thing; it can be traced to the times of remote antiquity. Its scientific adoption to industrial purposes commenced, however, not earlier than about the year 1860. In 1870 it was used during the great siege of Paris in France when the city's supply of coal had been exhausted and we are told it was the means of enabling the city to keep several of its large factories going and to grind its flour by steam while it was begirt by its enemies.

Conditions will have to change very much before oil can come into general use as fuel for industrial purposes by reason of its greater cost at present as compared with that universal fuel, coal. In favored countries or districts, however, where the supply is plenteous and close at hand, or where coal is more remote and the difficulty of cost does not stand in the way of its economical use, it seems certain that oil will be more and more used because the mechanical difficulties attending its use are one by one being overcome. More than a decade ago in the Caspian region where petroleum is plentiful the apparatus for its consumption had been measurably perfected and oil for fuel had replaced wood and coal on all the steamers plying on the Caspian Sea and on the locomotives of the Trans-Caucasian Railway as well as in the furnaces and factories of that district.

With the discovery of new sources of oil supply in America its availability as fuel on loco-

motives has become general in certain districts, and it is not unreasonable to suppose that further supplies will be found and the field for its use be correspondingly enlarged, so that the subject has become, and will be in the future, of great interest to those concerned with the motive power of our railroads.*

Petroleum as a fuel for locomotives is said, apart from the economic question of cost, to be infinitely superior to coal: It is smokeless; free from dirt and dust; can be instantly lighted; requires no stoking; can be regulated instantly and easily; requires much less storage room, and its calorific power for purposes of generating steam is several times greater than that of ordinary coal. There are, in fact, many things to be said in its favor for this purpose but few against it: While it is true that its use reduces the life of the flues and firebox about twenty-five per cent yet, on the other hand, it emits no sparks to cause conflagrations along the right of way or set fire to stations, buildings, or equipment; the cost of handling it is at least seventy-five per cent less than coal; no clinkers have to be removed at terminals or on the road; its use reduces the time consumed in turning the engine; it makes no refuse or cinders to be taken care of; it insures freer steaming and freer running loco-

*In the United States it is said that oil for locomotive fuel at $1.00 per barrel is an economical equivalent of coal at $4.00 per ton. At some points where oil is now obtainable at the price mentioned coal costs from $7.00 to $8.00 per ton. Its great economic value under such circumstances is apparent.

motives and consequently affords greater ability to handle maximum loads; furnishing a uniform grade of fuel, it becomes practicable to adjust draft appliances so as to get the best results under all conditions; owing to the easy and exact regulation of the fire possible, the greatest economy in firing is possible, as the labor of firing coal conduces to extravagance in its use; and, finally, the fuel supply can be taken at stations simultaneously with water very rapidly and without waste.

STORAGE.

In the practical operation of railways, after the oil has been taken from the earth it is necessary to store it in reservoirs from which it is conveyed to supply or delivery tanks; an illustration showing the kind of tanks used and their location in relation to the water supply is shown in Fig. 2.

These supply tanks are often located opposite the water tanks so that fuel and water can be taken simultaneously. In the construction of these tanks it is generally necessary to make provision for heating their contents so as to insure the oil flowing freely in cold weather. The accompanying illustration (Fig. 3) shows the details of the construction of a supply or delivery tank.

SPECIAL ADAPTATION OF LOCOMOTIVES—THE TENDER.

Locomotives on which oil is used for fuel must be specially adapted for the purpose. From the

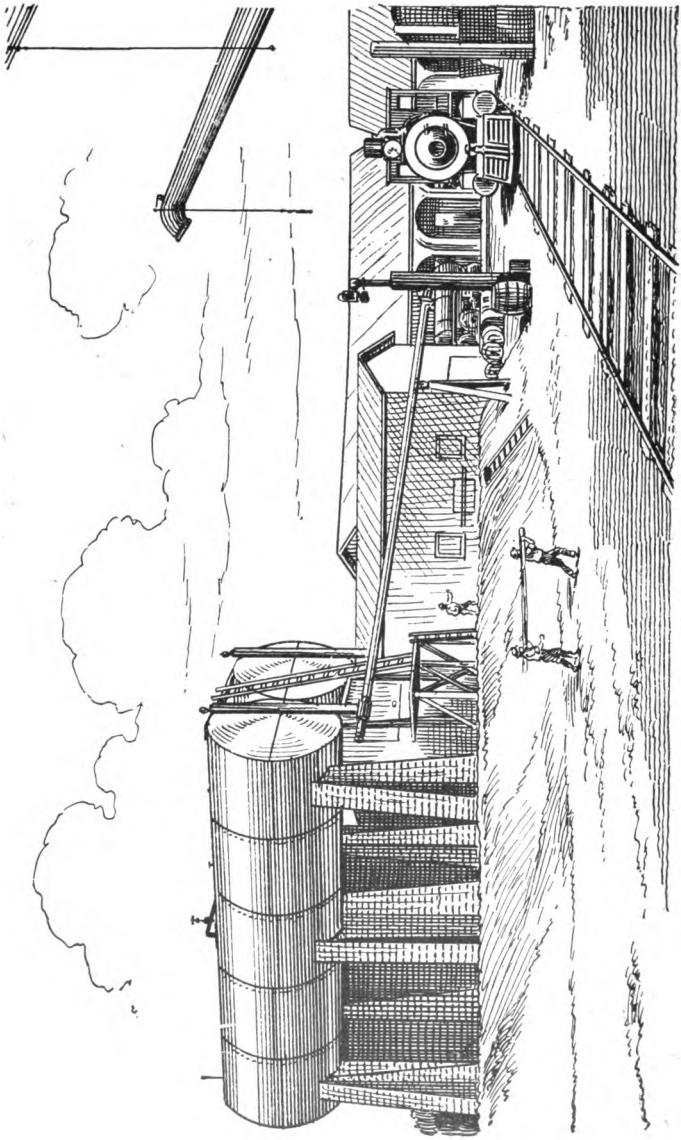


FIG. 2.
OIL AND WATER STATION.

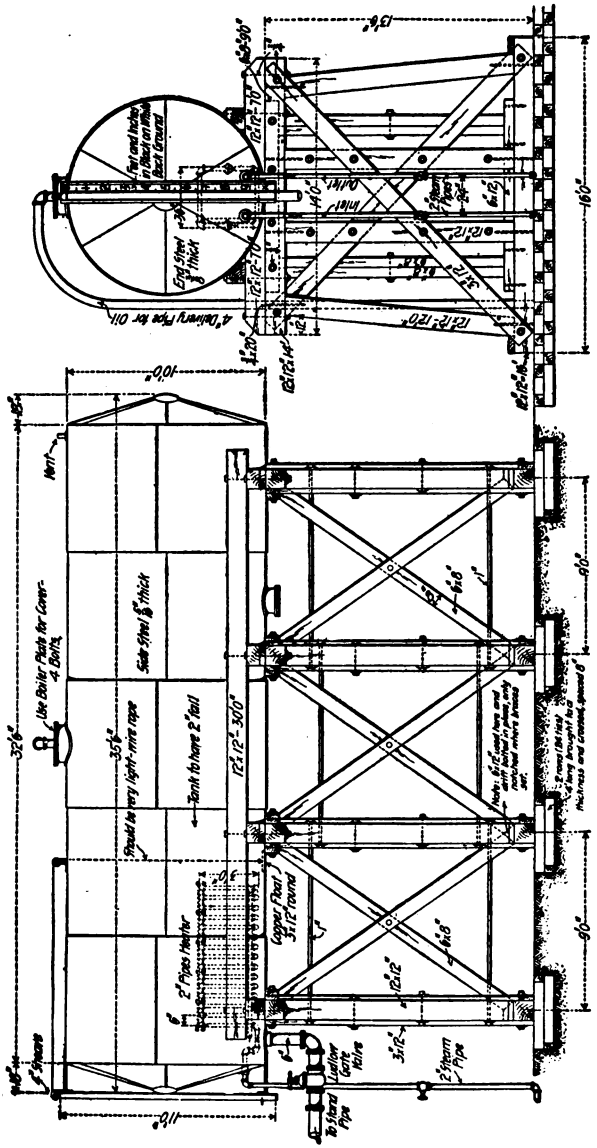


FIG. 3.

DETAILS OF CONSTRUCTION OF SUPPLY OR DELIVERY TANK.

delivery or supply tank the oil is conveyed to a tank in the tender which is generally a separate receptacle fitted in the space ordinarily used for coal. The arrangement of the tender is indicated in the following illustrations. Figure 4 shows the outside appearance of a tender equipped for oil burning.

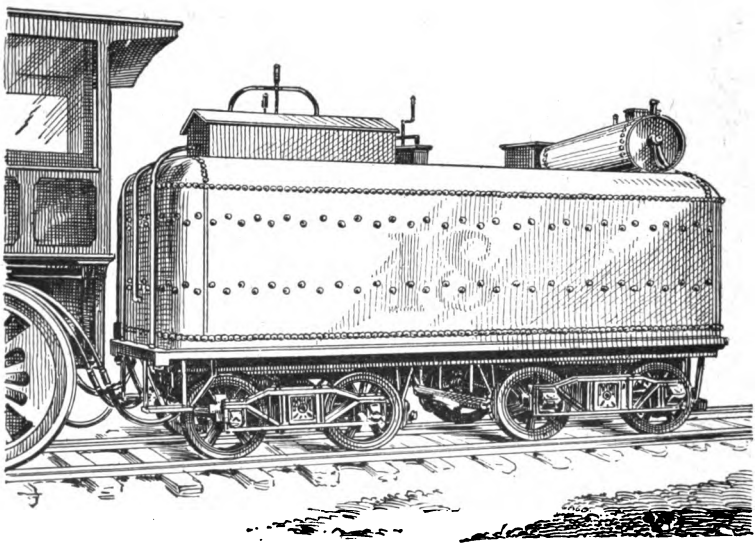


FIG. 4.

APPEARANCE OF TENDER EQUIPPED FOR OIL BURNING.

Figure 5 shows the details of the tender equipment as used on the Southern Pacific Railway.

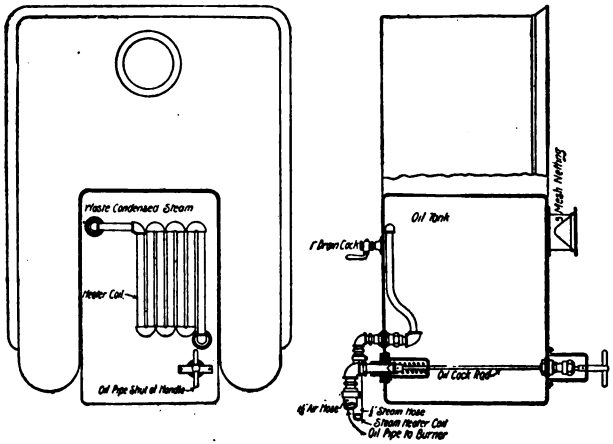


FIG. 5.

DETAILS OF TENDER EQUIPMENT—SOUTHERN PACIFIC.

Figure 6 shows the arrangement of piping on the tender as adopted by the Santa Fe system.

THE HEATER COIL IN TENDER.

As in the case of the supply or delivery tank so also the oil tank on the engine tender must be provided with a heater coil to which in cold weather steam can be admitted from the boiler so as to reduce the oil to a proper consistency. This heater coil is illustrated by Fig. No. 7.

THE PIPING AND APPLIANCES ON TENDER AND ENGINE.

The oil tanks in the engine tender are fitted with automatic safety valves with a small chain or rope connection to the back of the engine cab

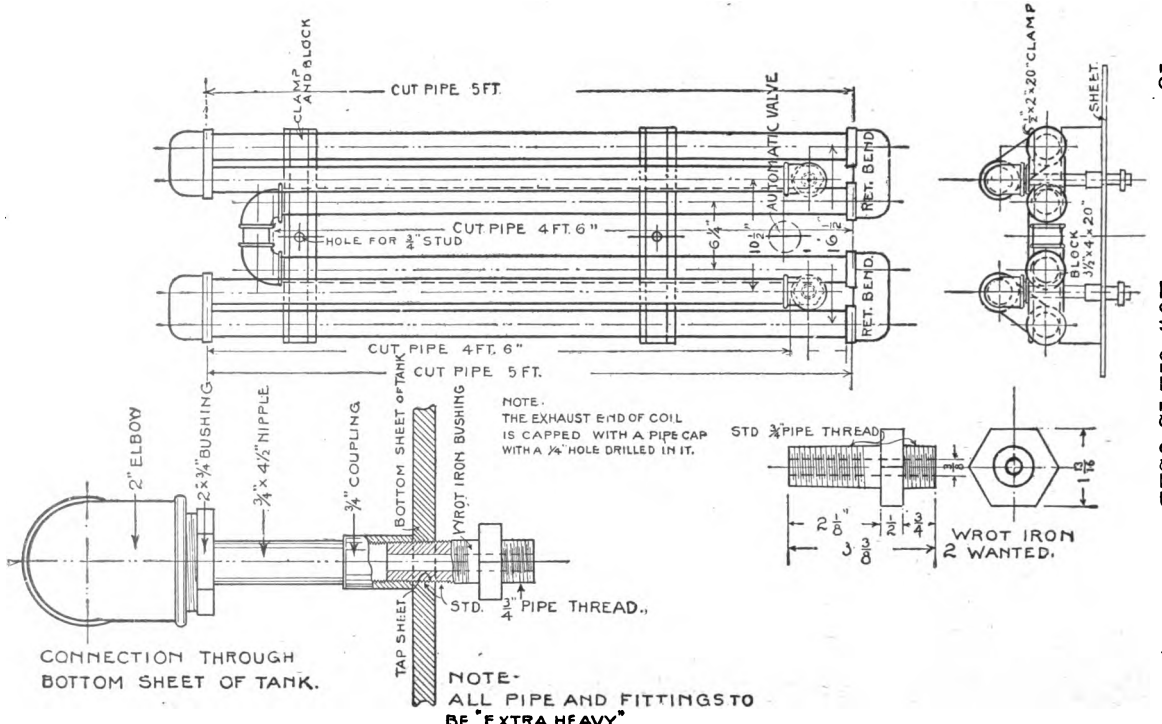


FIG. 7.

HEATER COIL—SANTA FE.

with a spring key which passes through the upright rod of the safety valve so that in case the engine breaks apart from the tender the rope or chain will pull the spring key out of the rod when the safety valve will close automatically and stop the flow of oil from the tank.

The following illustrations, Figures 8, 9, 10 and 11 indicate the details of the piping on the tender, the safety valve, the delivery pipe and fittings and the hose and fittings as used on the Santa Fe system.

In localities where heavy oil is used it is necessary to carry about five pounds pressure in the tender oil tanks to facilitate the proper flow of the oil. With light gravity oil, however, and in warm weather such pressure is not necessary. The illustration, Fig. 12, shows very clearly the general arrangement of an oil burning locomotive.

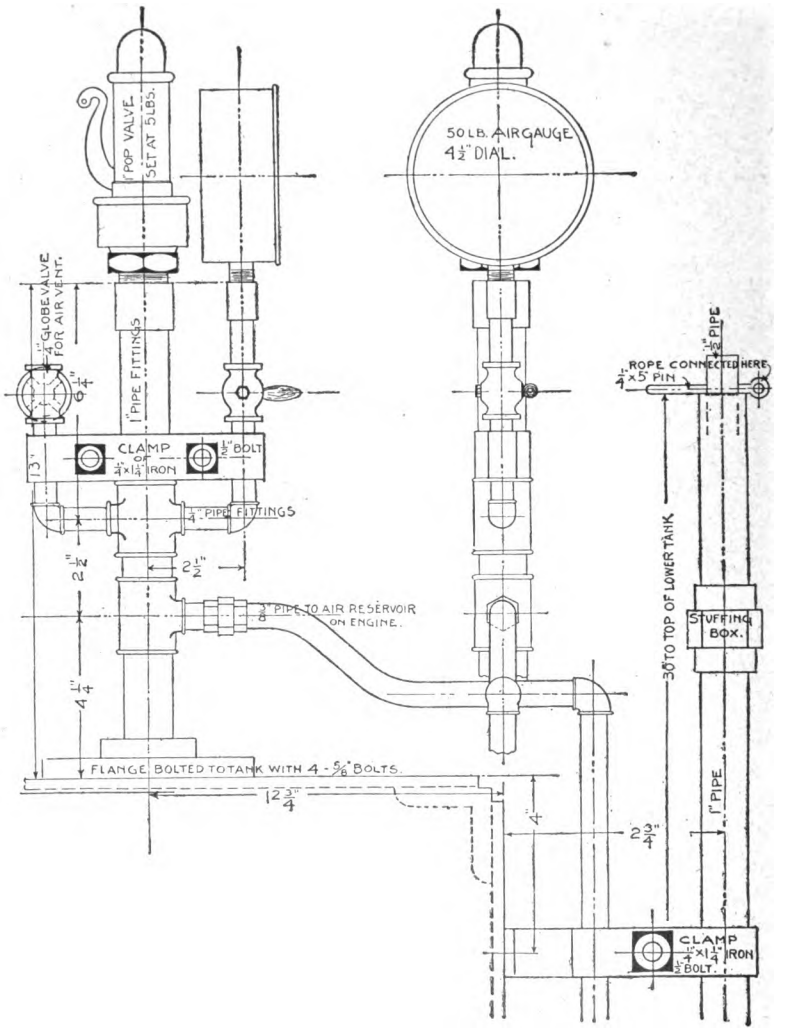

1" POP VALVE SET AT 5 LBS.
50 LB. AIR GAUGE 4½" DIAL.
¼" GLOBE VALVE FOR AIR VENT.
1" PIPE FITTINGS
CLAMP
¾" x 1¼" IRON
½" BOLT
¼" PIPE FITTINGS
¾" PIPE TO AIR RESERVOIR ON ENGINE.
FLANGE BOLTED TO TANK WITH 4 - ⅝" BOLTS.
1" PIPE
ROPE CONNECTED HERE
¾" x 5" PIN
30" TO TOP OF LOWER TANK
STUFFING BOX.
CLAMP
¼" x 1¼" IRON
⅜" BOLT.

FIG. 8.

DETAILS OF PIPING ON TENDER—SANTA FE.

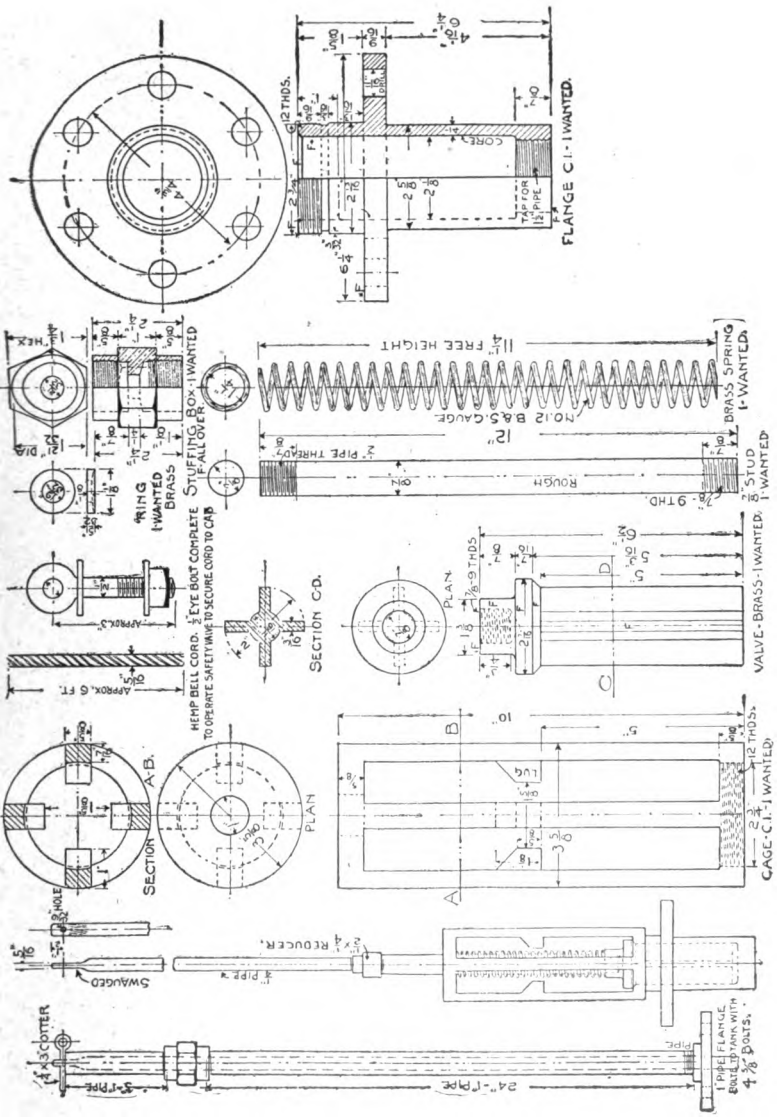


FIG. 9.

DETAILS OF SAFETY VALVE—SANTA FE.

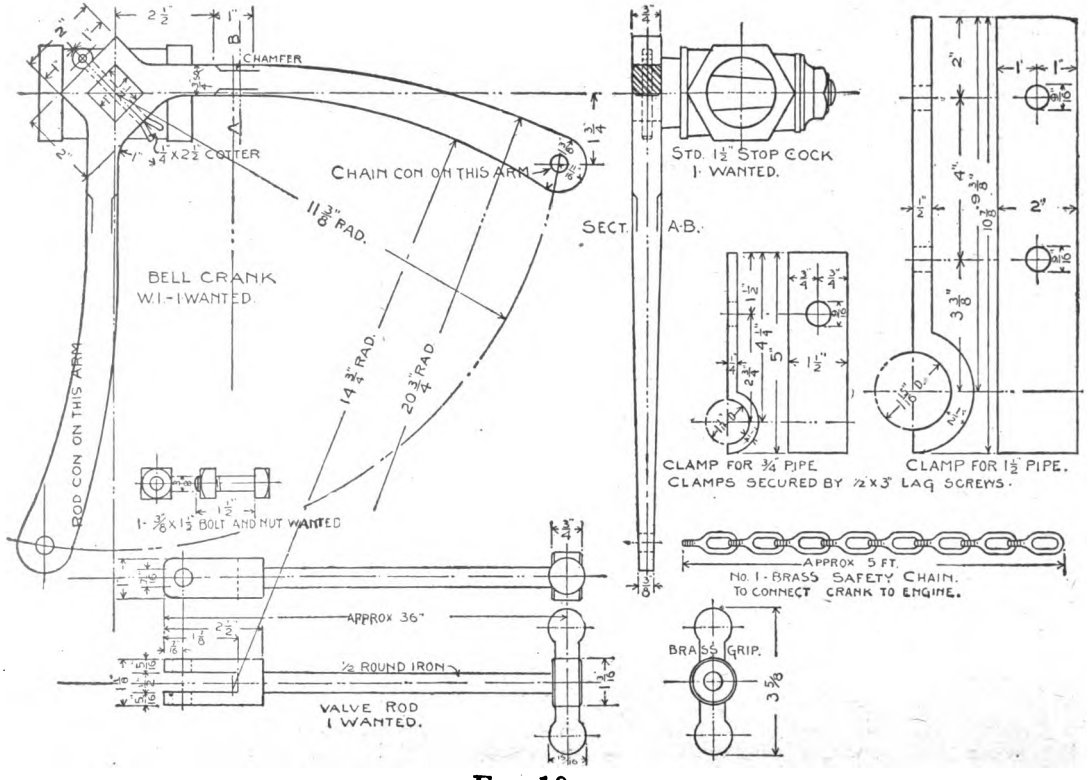


FIG. 10.

DETAILS OF OIL DELIVERY PIPE AND SPECIAL FITTINGS—SANTA FE.

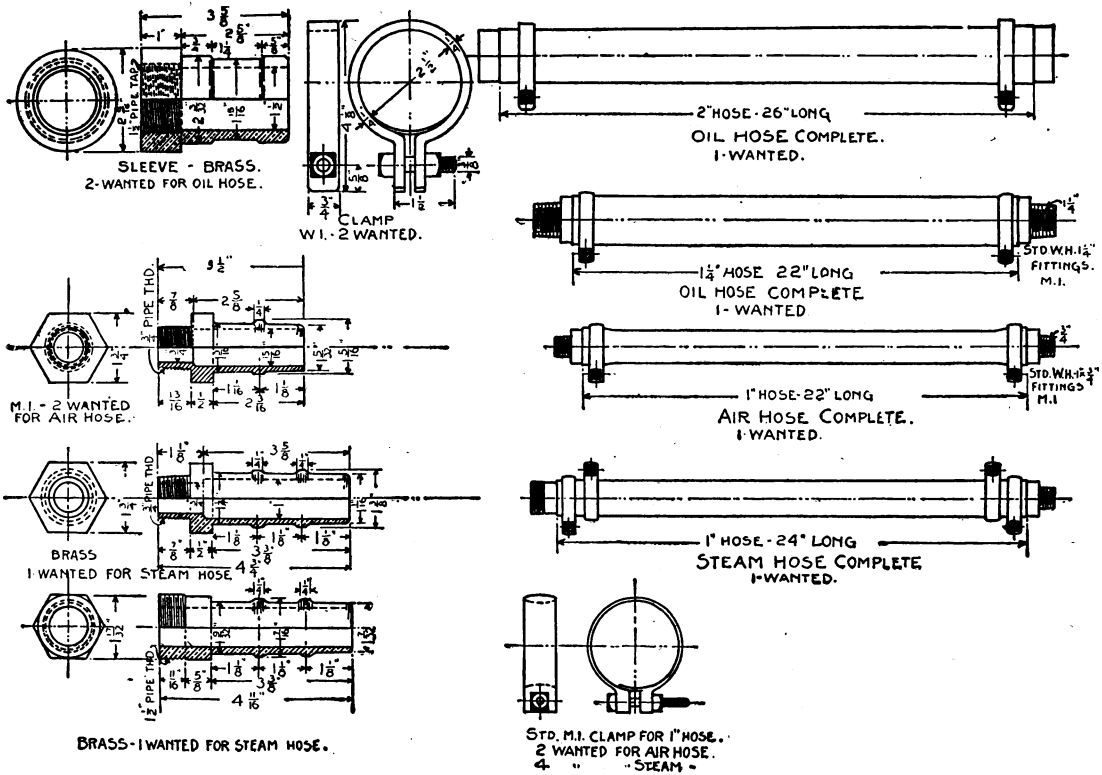


FIG. 11.

DETAILS OF HOSE AND FITTINGS—SANTA FE.

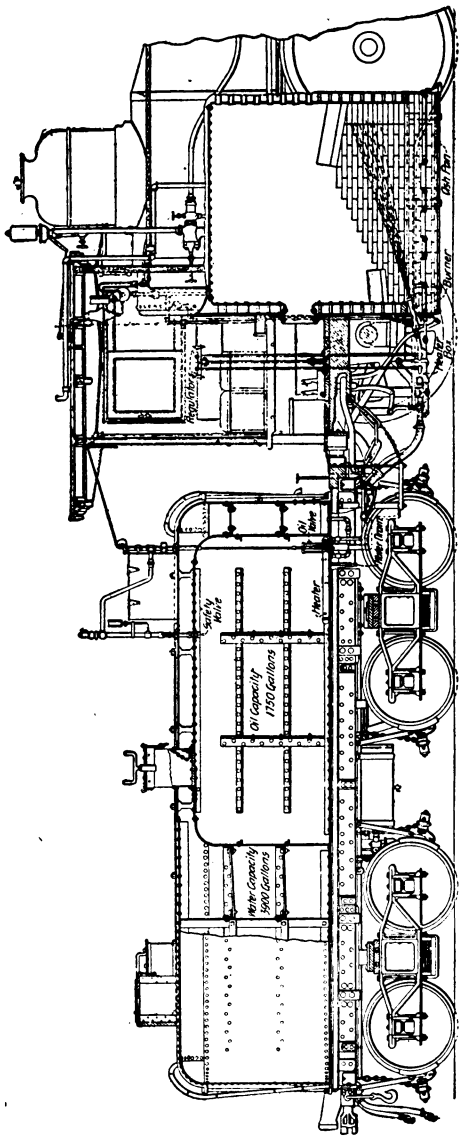


FIG. 12.

GENERAL ARRANGEMENT OF OIL BURNING LOCOMOTIVE—SANTA FE.

THE LOCOMOTIVE. CONVERTING A COAL BURNER TO AN OIL BURNER. PIPING AND BRICK WORK IN LOCOMOTIVE.

The locomotive shown in Fig. 12 is one converted from a coal burner to oil and shows the position of the different parts of the oil apparatus. In converting a coal burning engine to an oil burner it is necessary first to remove the grates and grate frame and remodel the ash pan by applying a suitable casting fitting the inside of the pan and riveted on the sides and near the top of the pan; this casting acts as a support for the brick work on the sides of the fire box and is cored out to admit the proper amount of air necessary for combustion to the fire box. The brick arch should be built as low as possible, the main purpose of which is to protect the crown sheet, crown bolts and seams from overheating. The oil burner should be secured to the bottom of the mud ring exactly central and should be placed at such an angle that the jet or spray of oil will strike just below or under the arch. Details of the arrangements of piping and brick-work of an oil burning locomotive are given in the accompanying illustrations, (Figs. 13 and 14.)

The details of the fire brick used in the construction of an oil burning locomotive are shown in the drawing, Figure 15.

For the side walls and inverted arch ordinary commercial fire brick is used. Experience has shown that fire bricks which soften under heat are preferable as they form a bond which adds

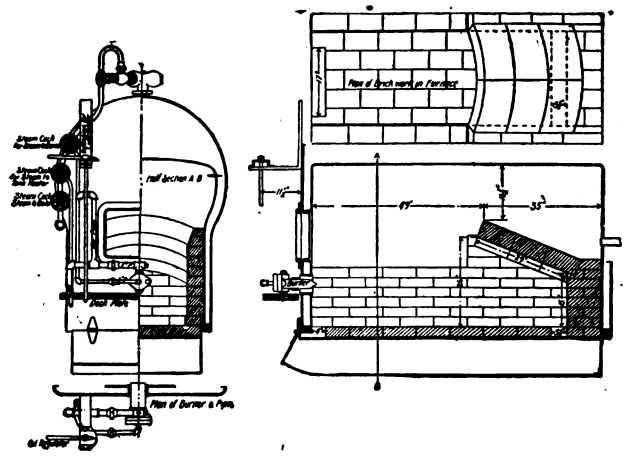


FIG. 14.

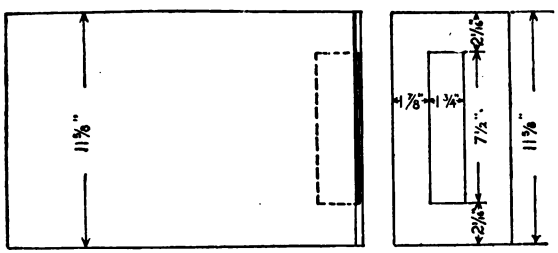
FIREBOX EQUIPMENT—SOUTHERN PACIFIC.

strength to the wall and prevents it shattering under the shocks incident to the service. Fire bricks which have very high heat-resisting qualities and which tend to crock when cooling are said to be of little use.

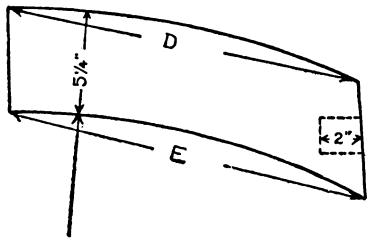
THE BURNER OR ATOMIZER.

One of the principal devices essential to the oil burning locomotive is, of course, the burner or atomizer, of which several designs are illustrated in the following drawings. (Figs. 16, 17, 18 and 19).

The function of the burner or atomizer is to break up the oil into a very fine spray. It is made of brass. In the Santa Fe burner, steam

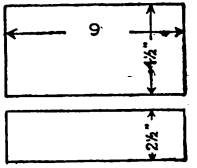


THIS STYLE ARCH BRICK USED WHERE SIDE WALLS EXTEND UP ONLY OF SUFFICIENT HEIGHT TO PROTECT MUDRING. RIVETS ARCH BEING SUPPORTED ON STUDS

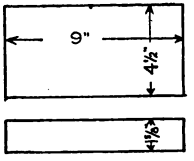


ARCH BRICK SUPPORTED ON STUDS			
BRICK NUMBER	NO. BRICK TO A SET	D	E
22	2	17"	17½"
23	2	18"	18½"
24	2	19"	19½"
25	2	20½"	21"

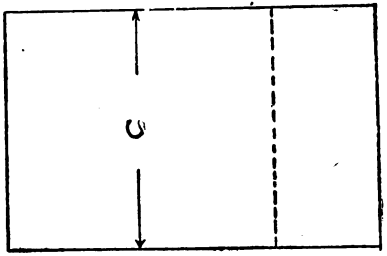
52" R



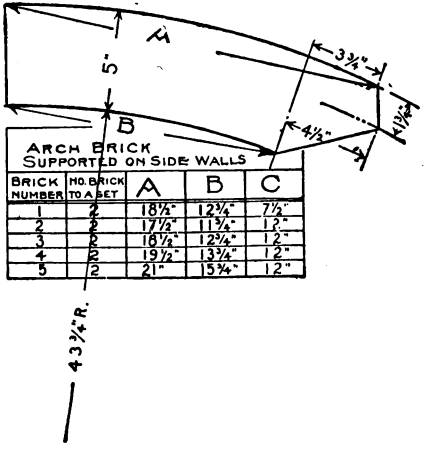
BRICK USED FOR END AND SIDE WALLS



BRICK USED FOR LINING BOTTOM OF FIRE BOXES.



THIS STYLE ARCH BRICK USED WHERE SIDEWALLS EXTEND UP TO AND FORM SUPPORT FOR THE ARCH.



ARCH BRICK SUPPORTED ON SIDE WALLS				
BRICK NUMBER	NO. BRICK TO A SET	A	B	C
1	2	18½"	12¾"	7½"
2	2	17½"	11¾"	12"
3	2	16½"	12¾"	12"
4	2	19½"	13¾"	12"
5	2	21"	15¾"	12"

FIG. 15.

DETAILS OF FIRE BRICK—SANTA FE.

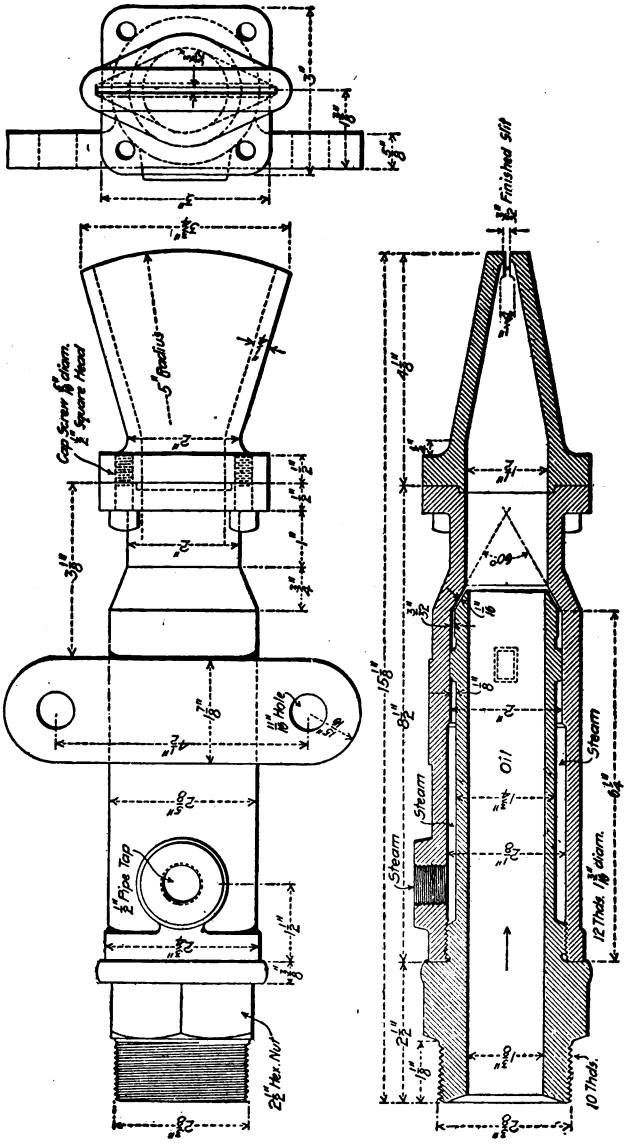


FIG. 16.

DETAILS OF "LUNDHOLM" FUEL OIL BURNER.

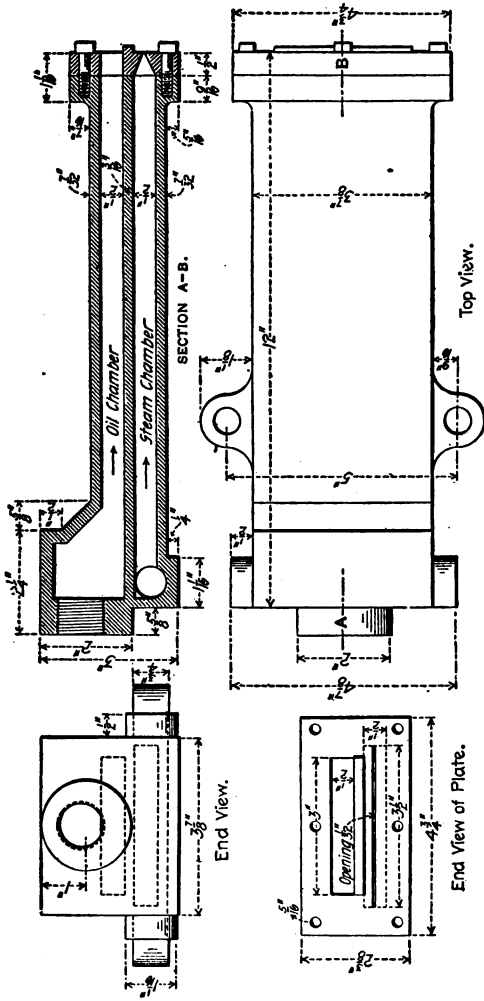


FIG. 17.

DETAILS OF "BOOTH" FUEL OIL BURNER.

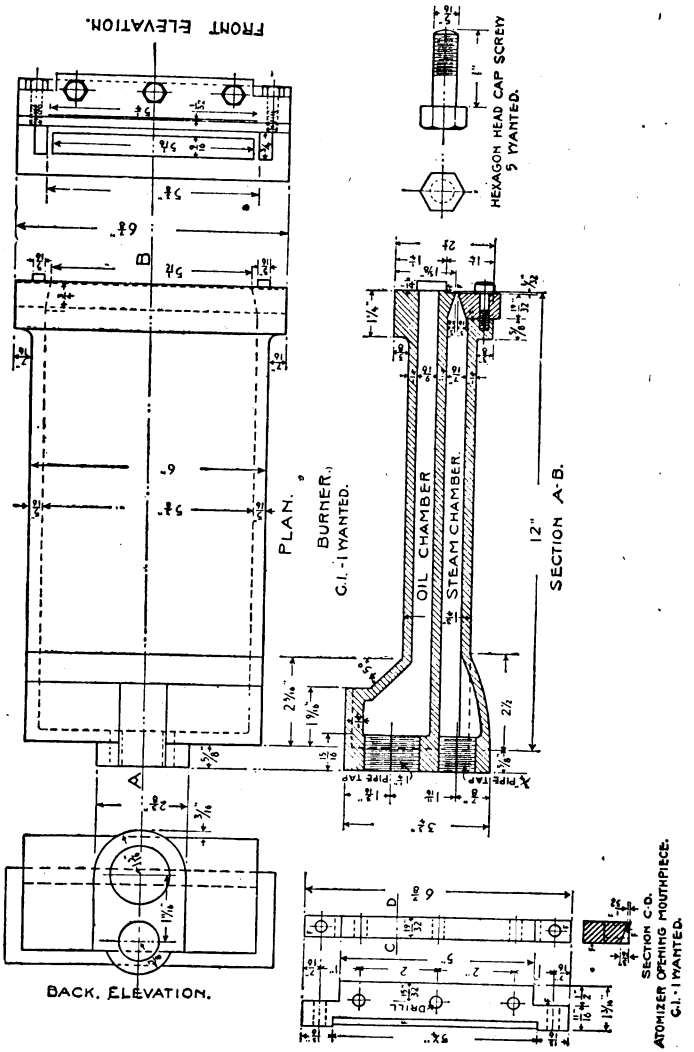


FIG. 18.

DETAILS OF OIL BURNER—SANTA FE.

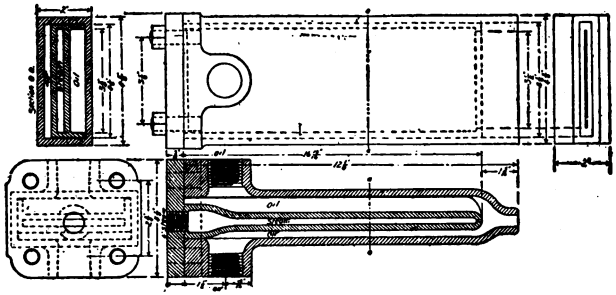


FIG. 19.

DETAILS OF OIL BURNER—SOUTHERN PACIFIC.

enters the bottom part at one end and issues through a slit at the other end. The oil flows through the upper part of the burner over the hot partition and on issuing is caught by the steam and sprayed into the fire, which, when the engine is working, is a mass of flame filling the fire box. The supply of steam and oil to the burner is regulated by the fireman from the cab, the handles of the steam and oil supply valves being located so that he can readily manipulate them from his seat.

The Santa Fe burner is rigidly attached to the mud ring; it is a casting having an oblong passage. One end of the casting is enlarged to receive connection with oil and steam pipes one above the other. The mouth of the steam passage is directly underneath the mouth of the oil passage and the effect of the steam pressure is to spray the oil as it flows from the upper passage.

In the Southern Pacific burner there are three passages: one for oil, one for steam, one for air. The oil enters the rear of the burner from above, air is conveyed from below through a narrower passage to a common mouth just behind which terminates a central tube supplying steam. The mixture of oil, air and steam is there sprayed into the fire box through one nozzle. In the Southern Pacific arrangement the burner is located near the upper part of the bricked portion of the fire box probably for the reason that the form of nozzle causes the spray to be thrown down as well as up.*

THE HEATER BOX.

In order to provide against the effect of cold weather, or where the oil is heavy or lacking in fluidity, a heater box is placed between the burner and the oil tank the purpose of which is to raise the temperature of the oil to as high a temperature as possible before it goes into the burner. The construction of this box is shown in the following illustration, (Fig. 20).

---

*The methods adopted for using oil for fuel have advanced step by step as is the case with all mechanical devices. First came the *Hearth furnace* in which the liquid is thinly distributed in pans or other receptacles and burned; then the *Gas furnace* in which the oil is transformed into gas before combustion, and, finally, the *Atomizer* by which the oil is divided into atoms so that it can be nearly completely consumed in a vaporous condition. The atomizer is the device adopted and used on American locomotives. It is certain however that the final stage has not been reached in the development of mechanical appliances for the combustion of oil.

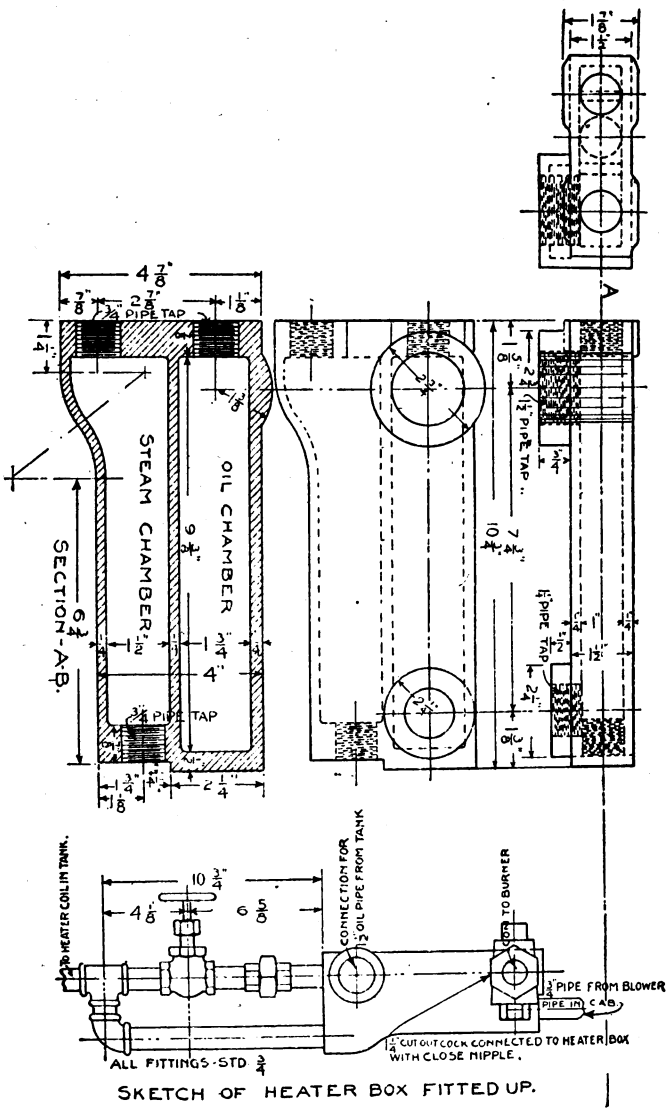


FIG. 20.

DETAILS OF OIL HEATER BOX—SANTA FE.

CAB APPLIANCES.

Detail drawings of the three way cock blower pipe connection to smoke arch and of the oil throttle valve handle are shown in the following drawings, (Figs. 21 and 22).

CLEANING FLUES. SAND FUNNEL.

In the operation of the oil burning locomotive it becomes necessary occasionally to remove the gum and soot generated in the combustion of the oil from the boiler flues. To effect this a funnel is used which is inserted in the fire door through which sand is blown by steam with force, the sand thus blown through the flues carrying with it the accretions of soot. A detail drawing of this funnel is shown in Fig. 23.

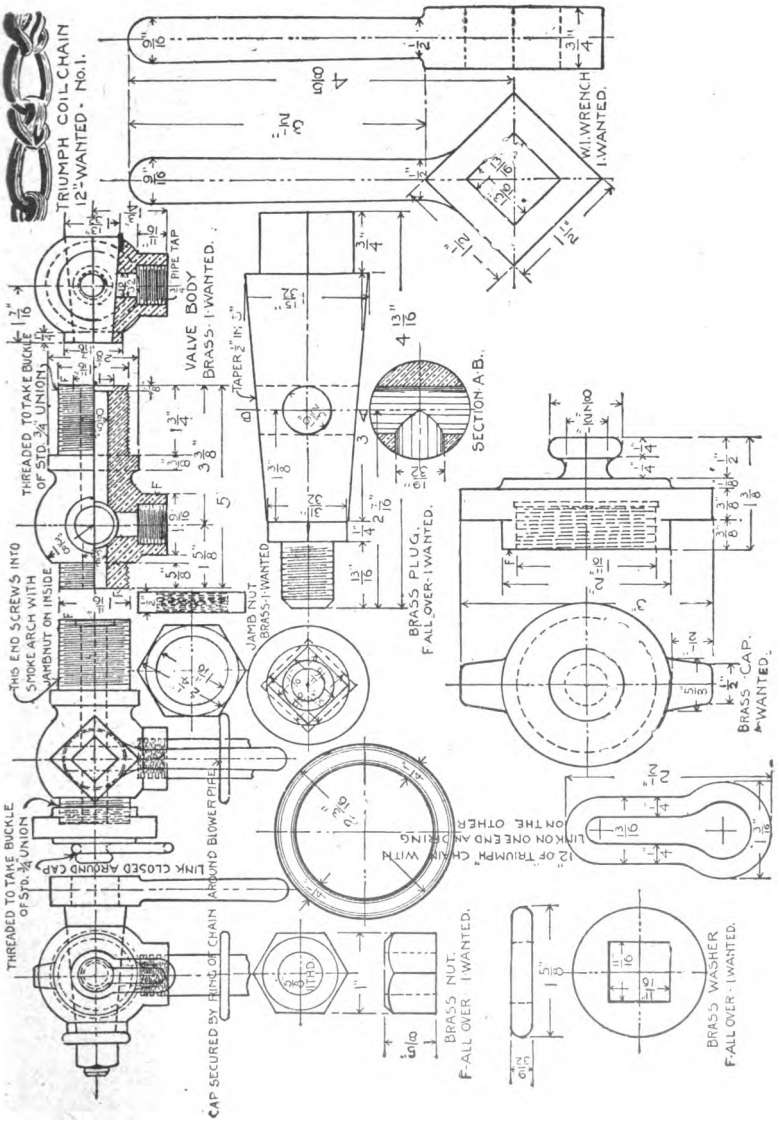


FIG. 21.

DETAILS OF THREE-WAY COCK—SANTA FE.

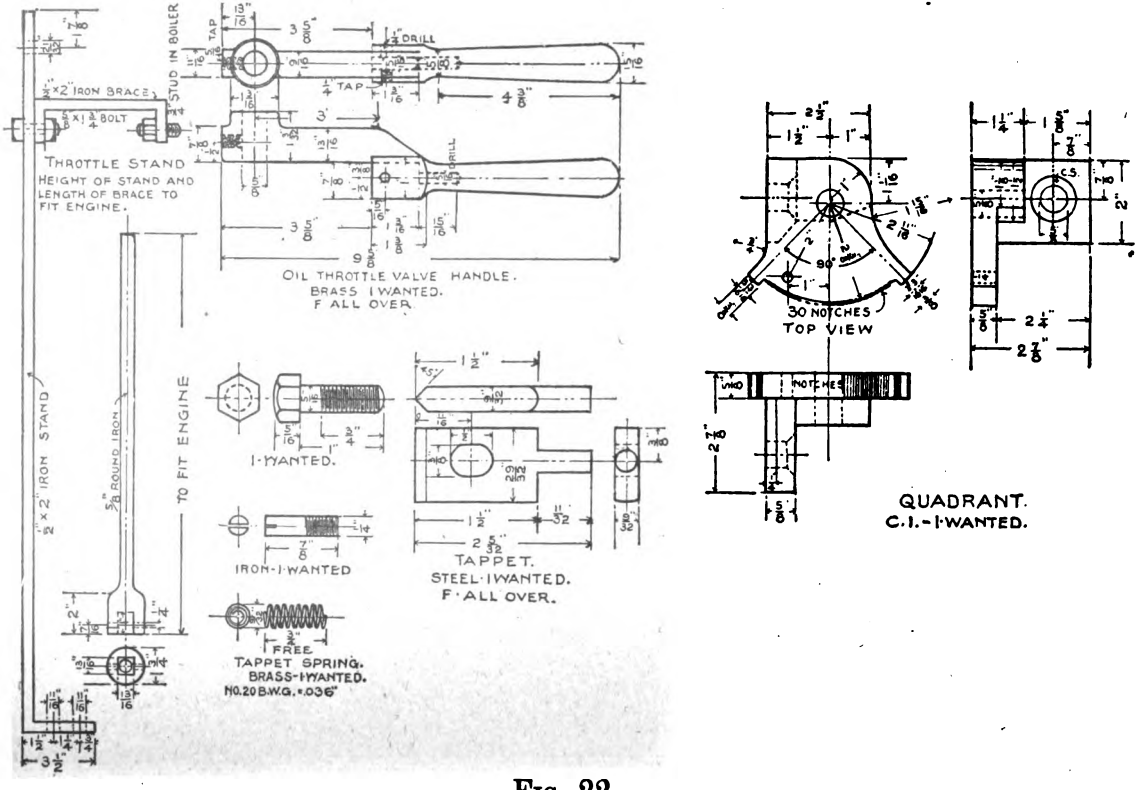
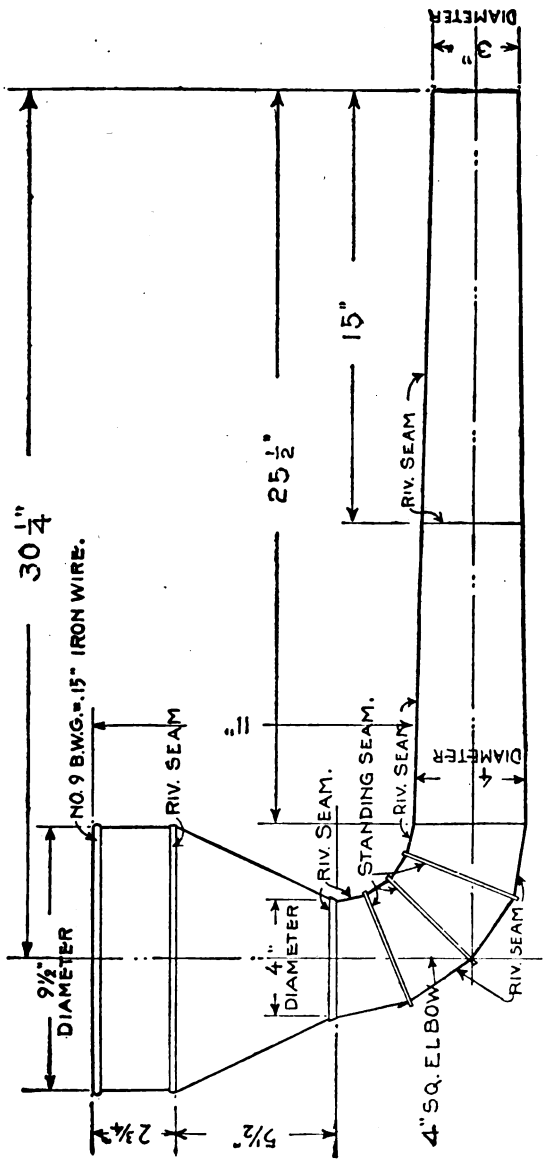


FIG. 22.

DETAILS OF OIL THROTTLE VALVE HANDLE—SANTA FE.



MATERIAL NO. 26 GALV. IRON.
ONE POUND RIVETS.

Fig. 23.

SAND FUNNEL USED IN CLEANING FLUES—SANTA FE.

SPECIFIC RULES TO BE OBSERVED IN FIRING AND OPERATING.

In the operation of oil burning locomotives the following practical rules and regulations have been adopted:

In firing up an oil burning locomotive in the round house steam connection is made to the three way cock on the smoke arch which acts as a blower and atomizer at the same time; then throw in the fire box, in front of the burner, a piece of greasy lighted waist; then start the oil to running slightly; then open the atomizer valve enough to atomize the oil which is flowing from the burner, and the oil will instantly ignite. The fire should be watched until steam begins to generate in the engine, when the round house steam can be cut off. Care should be taken not to turn on too much oil, for the explosion would drive the flame out of the fire box and might be the cause of injury to the operator. Care must also be taken to see that the fire does not go out when first started in a cold engine; if it does and is not noticed the oil will run into the pit and may take fire later on and explode and thus damage the engine. The fire must therefore be carefully watched until its burning is well assured after which there is little danger of this happening. Fire going out on an oil burning engine can be detected readily by observing the smoke coming out of the stack. If it is of a white, milky color, it indicates that the fire has gone out and that the oil is still running out into the

pan; this smoke is caused by the heat of the brick in the bottom of the pan. That the fire has gone out can also be detected by the odor.

In firing up an oil burning locomotive where steam is not available, wood may be used until ten or fifteen pounds of steam is generated in the boiler. The wood must be placed in the fire box with great care so as not to damage the brick work, and in using wood for this purpose care must be taken to avoid causing fires along the right of way or elsewhere.

It is very important that the proper amount of steam be admitted to the burner as an atomizer. It is also very important that the brick walls and arch of the locomotive be kept in perfect condition. Occasionally small pieces of brick will fall down and lodge in front of the burner, which will interfere with the engine steaming. All engines should be equipped with a pair of light tongs or a hook so that the fireman can remove these pieces of brick if necessary.

In oil burning engines it is necessary to occasionally use sand for cleaning the gum off the end of flues in the fire box. This sand is applied through an elbow-shaped funnel made for the purpose; the nozzle of the funnel is inserted through an aperture in the firedoor, and when sand is being applied by the fireman the engineer drops the lever in the corner notch and has his throttle wide open. This is very effective, and is only used three or four times in going over a long hard division.

In handling the oil burner on the road the engineers and firemen must work in harmony,

i. e., when an engineer wishes to shut off the throttle he should notify the fireman in time so that the latter can close the oil valve in order to prevent waste of oil, the emission of black smoke and the "popping off" of the engine; and again, in starting up, the engineer should notify the fireman so that the oil valve may be opened before the throttle, and the fire burning before any cold air is drawn into the fire box by the exhaust. In opening the valve the flow of oil should be gradually increased as the engineer increases the working of the engine. If this rule is carried out it will in a great measure prevent leaky flues, crown and stay bolts. Fire boxes can be easily damaged by over-firing.

In a coal burner if an engine drops back five or ten pounds pressure it takes some little time to regain it; in an oil burner the fire can be crowded so as to bring it up almost instantly and thereby overheat the plates and cause damage to the fire box. The practice should be to consume about as much time in bringing up steam on an oil burner as would be taken with a coal burner; too much care cannot be exercised in this particular. It is possible to melt the rivets off the inside of an oil burner fire box by over-firing.

In drifting down long grades, it is preferable to keep the fire burning a little rather than to shut it off entirely to prevent chilling of the fire box, adjusting the dampers to suit a light fire. The water can be carried in such a way approaching such points as will admit of working the injector occasionally to prevent popping off.

The use of the blower should be restricted all possible. It tends to make the fire box leak. If the blower is used at all it should be used very lightly, simply enough to cause a draught.

Some troubles have been encountered on account of waste getting into the oil tank; these are caused by carelessness on the part of Hostlers and Helpers in measuring the oil and wiping the measuring stick off with waste. Waste should therefore not be used for this purpose.

Do not approach the man hole or vent holes of a tank closer than ten feet with a lighted torch or lantern.

Do not take a lighted torch or lantern to a man hole to ascertain the amount of oil in the tank; this should be done by the insertion of a stick or rod and the same carried to the light to ascertain the number of inches of oil shown on the stick or rod.

Do not, when making repairs to, or inspection of, an empty tank, place a lighted lamp or torch inside of the same before it has been thoroughly steamed and washed out, as gas will accumulate in an empty tank not so steamed and washed out, and explosion is liable. Employes are positively prohibited from entering tanks having contained crude oil, until the instructions to thoroughly steam and wash them out have been complied with.

Do not, in firing up, apply the atomizer and oil before putting in the lighted waste, as gas may accumulate in the fire box and thus cause an explosion.

In starting up or stopping, the engineer must always notify the fireman, as the starting or shutting off of fire must in all cases precede the opening and shutting off of the engine.

Do not force the firing. Bring the fire box temperature up gradually. If pressure falls back five or ten pounds, restore the maximum pressure by gradual degrees. Forced firing will overheat the plates, burn off rivet heads, and cause leaks.

In sanding the flues to clean out the accumulations of soot and gum, drop the lever to half stroke and use full throttle for a few turns, while the sand is being injected.

Successful combustion of petroleum is smokeless.

An accurate combination of steam and oil in the atomizer and air admission is necessary to thorough combustion. To this end the steam and oil valves and dampers must be adjusted closely.

As all petroleum contains a greater or less per cent of volatile gases, which are given off at low temperatures, lighted torches, lamps or lanterns should never be taken in or near tanks containing oil.*

The following rules are enforced by another Company,† viz:

Before departure, see that the oil tanks are full, the oil heater in operation and the oil heated to a proper temperature as soon as possible; also

* The foregoing rules are those in force on the Santa Fe system.

† The Southern Pacific. For further and more detailed rules of the Southern Pacific Company, together with drawings showing details adopted by that Company, the reader is referred to Appendix A.

that the fire is burning, that no oil is dropping or lying in the outer pan, that no brick or other obstruction to the free passage of oil from the burner to the front wall is lying on the bottom of the inner pan, and that the sand buckets are full.

Starting the Fire.—When the firebox is below igniting point, which is a dull red, open the dampers, start the blower and atomizer medium hard, throw a piece of saturated oily waste, after lighting same, on to the bottom of the inner pan, close and fasten the firebox door, then turn on the oil very light, and see if it ignites at once. If not, shut off the oil at once, and see if the waste is burning. When the oil has ignited, reduce the blower and atomizer to very light feed; also reduce the oil flow until the stack becomes almost clear. In starting the fire by the hot firebox, no waste is used.

Temperature of Oil.—Kern River or thick oil should be heated to from 150 to 170 degrees, McKittrick or thin oil to from 100 to 120 degrees; the temperature should be taken from the measuring rod suspended in the forward tank. Vents on the top of the oil tanks should be kept open at all times, except when tanks are very full and oil is liable to splash out, when they may be kept closed until the oil is reduced from 5 to 7 inches in the tanks, care being taken not to have any lights in the hands when they are first opened after having been closed any length of time.

Heating Oil by Direct Steam Application.—Put the heater on strong until the oil has reached

the proper temperature, then close it off and give it another application. To keep the heater on light and constant might produce water enough in the oil to become objectionable.

Heating by the Coil in Tank.—Open cock on boiler head just sufficient to produce steam water at drain cock under tank. Superheater should be used constantly when weather is anyway chilly. Keep drain cock to superheater open just sufficient to keep cylinder dry.

Starting Train or Engine.—The engine should not be started until the fireman is at the firing valve. Remember that the care of the fire box is as important as keeping up steam or making time. Start the engine carefully, so, if possible, not to slip engine. Open the firing valve sufficiently to make sure that the action of the exhaust will not put out the fire, but not enough to make a great volume of black smoke. Increase the atomizer and oil gradually until full speed is attained, keeping just on the verge of black smoke. When the engine is hooked up, the valves governing the admission of oil should be regulated according to amount required. It is well to use the blower about one-half turn while starting, as this will help to consume the smoke between exhausts and keep the engine hot.

Black Smoke.—Never make an excessively heavy smoke, as it only fills the flues with soot. Soot is a great non-conductor of heat and produces no heat in itself, therefore strive to keep the stack clear at all times except when starting.

Sanding Flues.—Sand as frequently as required, according to the amount of smoke made.

If the engine has to be smoked anyway hard, sand every 10 or 12 miles, but if the stack is kept clear, sand only every 30 to 50 miles. If any amount of switching is done at a station, sand immediately after leaving that station. How to sand: Having attained a fair rate of speed use about one quart of sand, close all the dampers, put the reverse lever near full stroke, open the throttle wide and allow the sand to be drawn from the funnel in a thin stream. Going into a station where stops are to be made great care should be exercised not to cut the oil supply too low before the throttle is closed.

Any draft through the fire box has a tendency to put the fire out; the stronger the draft the stronger must be the oil supply. Consequently there is great danger of the fire being put entirely out before the throttle is closed. When the throttle is closed and oil reduced, the atomizer should be cut down at once, so that it will just keep the oil from dropping onto the bottom of the inner pan, otherwise the intense heat of the fire box will be blown down through the air inlet burning the bottoms of the pans.

Never allow the fire to be put entirely out, except when giving up the engine at the end of a run or when all hands are going away from the engine. Then it must be put out. To put out fire: First close the stop-cock under the tank, allow the oil to all be drawn from the pipe and burner, then close the firing valve, atomizer and all dampers. To blow obstruction from oil line: Close the firing valve, open the cock between

the heater line and the oil line, close the heater line and turn the cock on boiler head to the heater line on full. This will blow all obstructions back into the tank. This arrangement may be used to heat the oil in the tank in case of failure of the coil heater. If any brick from the walls or arches in the fire box should fall in front of the burner, it must be removed at once or pushed to the extreme front of the fire box. Blue gas issuing from the stack is an indication that the fire is out or very nearly so; it is very objectionable and should be avoided if possible, especially on passenger trains.

Burners must be adjusted so that the oil will strike about the middle of the front wall. If the oil drops on the bottom of pan, black smoke and poor steam will be the result. Burners are liable to clog up with sand that is in the oil and by pieces of waste that are sucked up through the air inlet. If trouble is found with it, the inner case or steam jet can be taken out in most cases without disturbing the outer case or the adjustment of the burner. In this manner any obstruction or defect may be readily located and remedied. The blower should never be used stronger than just sufficient to clear the stack of black smoke. Any more is only a waste of fuel and a delay, as too strong a draft through a fire box for the amount of oil admitted only absorbs heat and cools instead of heating the fire box. At water tanks, where it is necessary to keep the injector on all the time the train is standing, the oil supply should be left on a little heavy and the

blower on lightly. This will insure a full head of steam when ready to start. As the oil penetrates the arch brick and causes them to crumble away very fast, it is important to examine the fire box frequently to know its condition. As steam pressure increases on the boiler, the atomizer and blower will work stronger unless they are cut down. Be governed accordingly. Also remember that black smoke is very detrimental to steam generating and that the more that is made, the more it becomes necessary to make.

THE BALDWIN OIL BURNING LOCOMOTIVES.

The following is a description of the devices used by the Baldwin Locomotive Works, many of whose oil burning locomotives are in use both in the United States and Russia.

The burner, shown in figure 24, is rectangular in cross-section, with two separated ports or chambers, (one above the other), running its

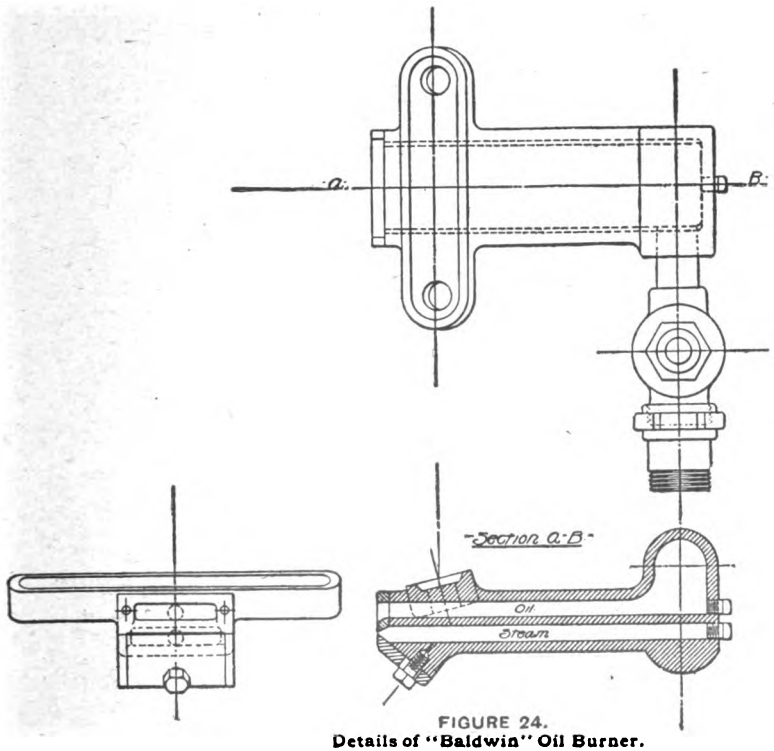


FIGURE 24.
Details of "Baldwin" Oil Burner.

entire length. Into the upper of these ports the oil from the reservoir is admitted through suitable pipes. The flow of oil is controlled by a plug cock in the feed pipe, provided with an operating handle placed in the cab within easy reach of the fireman. Steam is admitted to the lower port of the burner through a pipe connected to the boiler in such a manner as at all times to insure the introduction of dry steam. The valve controlling the admission of steam is also conveniently located in the cab close to the fireman's seat. A free outlet is allowed for the oil at the nose of the burner; the steam outlet, however, is contracted at this point by an adjustable plate which partially closes the port, and gives a thin, wide aperture for the exit of the steam. This arrangement tends to wire-draw the steam and increase its velocity at the point of contact with the oil, giving a better atomizing effect. A permanent adjustment of the plate can be made for each burner after the requirements of service are ascertained. The moving of the plate would not then be required except for cleaning purposes. The oil, as it passes through the burner, is heated to a certain extent by the effect of the steam in the lower portion, and flows freely in a thin layer over the orifice. It is here caught by the jet of steam issuing from the lower port, and is completely broken up and atomized at the point of igniting. The oil is carried into the fire box in the form of vapor, where it is mingled with a sufficient quantity of oxygen from the incoming air to insure as near as possible perfect

combustion. For the size of the burner it is computed that one inch in width is suitable for one hundred inches of cylinder area. The proper width of burner for any locomotive may therefore be obtained by the following formula:

$$B=\frac{C^2 \times .7854}{100}, \text{ in which}$$

B=width of burner in inches.
C=diameter of cylinder in inches.

The oil pipe leading to the burner should be made of ample size to insure a full supply, as it is essential that a regular flow be maintained; a small pipe would be found inadequate with oil having a sluggish tendency. Any interference with the flow, other than that interposed by the feed cock, causes a loss of efficiency.

At times, especially when the locomotive is standing still at stations or when drifting down grade, it is desirable to allow only a small supply of oil to enter the burner. To accomplish this, the feed cock, Figure 25, is used. The passageway through the plug of this cock, which regulates the supply of oil, is made square, as shown in the cross-section. As the plug is turned

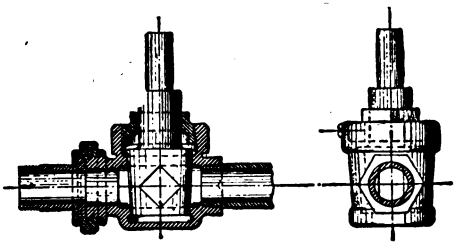


FIGURE 25.
Details of "Baldwin" Feed Cock.

to cut off the flow, the opening retains its angular form and a finer feed adjustment is attained than is possible with a cock of ordinary construction, where the hole in the plug is circular in form; it is also less liable under such circumstances to become clogged by refuse in the oil.

With a fire box such as is ordinarily used for burning coal, the changes necessary to adapt it for burning oil are easily accomplished. The general arrangement of a fire box of this description is shown in Figure 26. The burner is placed below the mud-ring at the back and on a line with the center of the boiler, and it is pointed upward at a slight angle to allow the spray to enter the fire box. A fire brick arch at the front of the fire box protects the tubes and gives direction to the heated gases, to insure their mingling with the incoming air. The throat sheet below the arch is protected with a wall of fire brick, and a layer of the same material is placed on the grate-bars (or equivalent supports), which extends back from the front wall covering about half the bottom area of the furnace. A fire brick hearth is placed under the burner to catch any oil which may drop from it. A course of brick is also placed on each side, sufficiently high to protect the side sheets of the furnace from excessive heat. A device correspondent to the ash-pan of an ordinary locomotive is fitted with a damper, preferably at the back, to govern the admission of air. This damper should be made as large as possible, with heavy frame, and arranged to close perfectly air-tight. Heavy

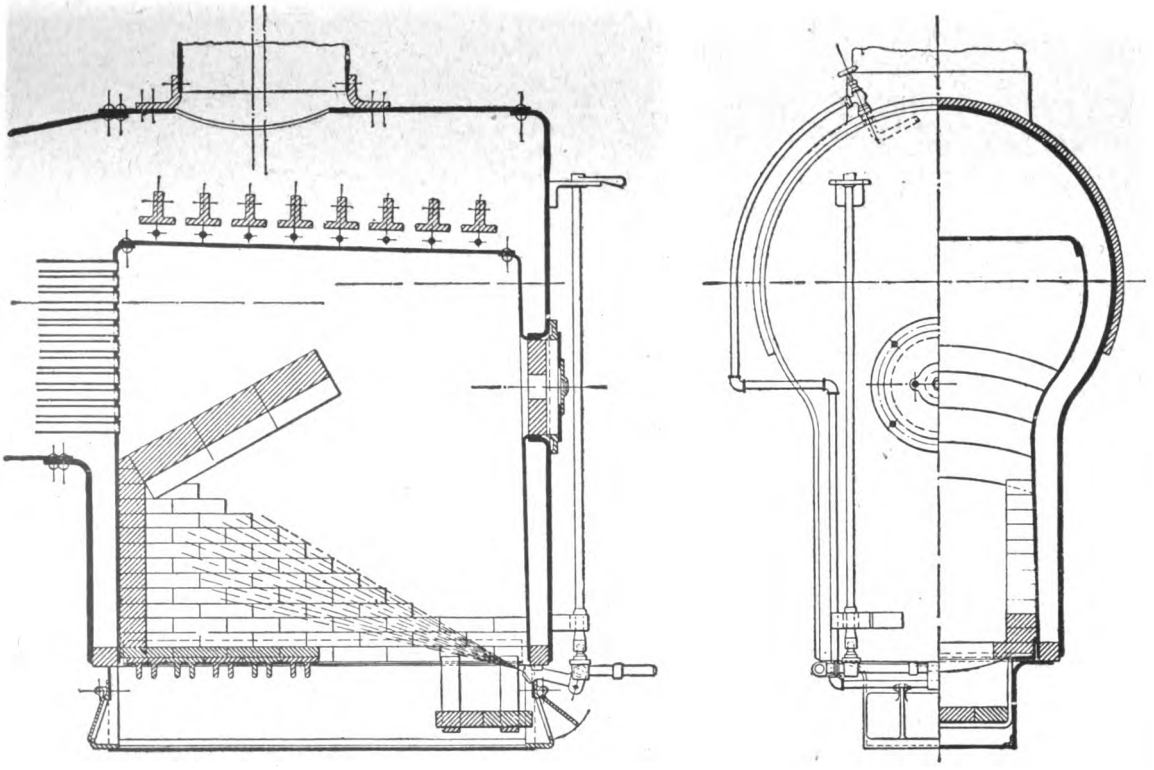


FIGURE 26.
Details of Fire-box Brick Work for Ordinary "Baldwin" Coal Burning Locomotive.

operating rods should be provided in order to withstand rough usage. The proper admission of air is an important feature, and the means for regulating it should be carefully adjusted to give a sufficient supply when needed for combustion, and on the other hand, to entirely stop the supply and avoid the loss of heat which would be occasioned by a circulation of cold air through the fire box and tubes when the oil supply is cut off. A plate with a convenient sight hole may take the place of the fire door, or the fire door may be retained, care being taken that the joints are perfectly air-tight; in either case a protection of fire brick should be provided for the inner surface to avoid the liability of warping the metal.

Boilers fitted with the Vanderbilt type of fire box have shown excellent results in burning fuel oil. This fire box, as is well known, is circular in cross-section, being rolled in the form of a large corrugated tube, and is peculiarly adapted to the class of fuel under consideration.

The arrangement of the fire brick used in the Vanderbilt type of fire box is shown in Figure 27. It is generally similar in arrangement to that already described, the only variations being those suggested by the structural changes in the boiler. The burner is introduced through the lined casing forming the back head of the boiler, and is located a short distance above the bottom of the fire box. The corrugated sheet forming the fire box is protected at the bottom and a portion of the sides by a lining of fire brick. The front wall and arch are placed at a suitable distance

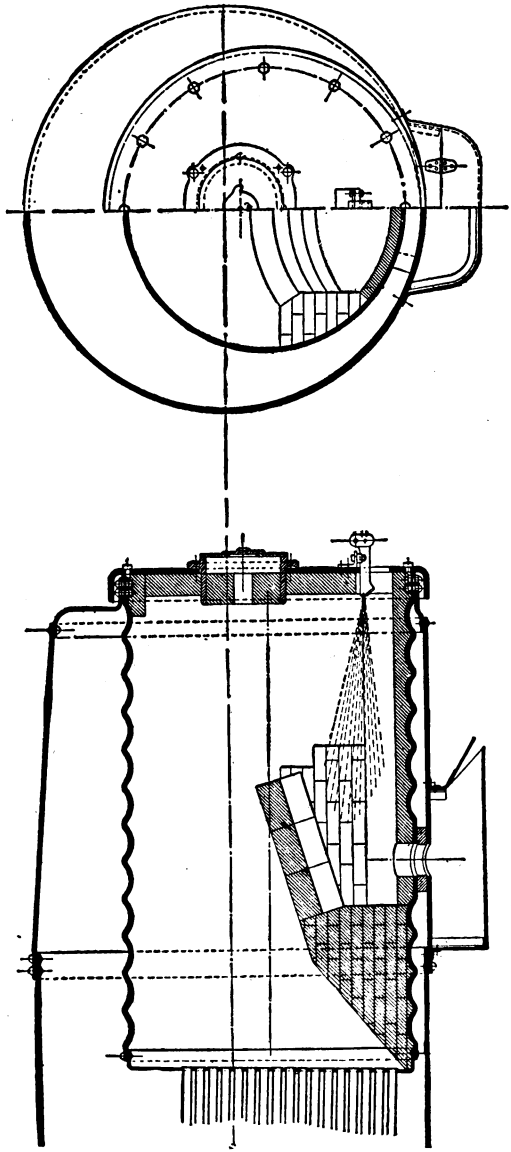


FIGURE 27.
Details of Fire-box Brick Work for "Vanderbilt" Type of Fire-box.

back of the tube sheet, to allow an unobstructed entrance to all the tubes by the heated gases, forming also a combustion chamber at the front of the furnace.

In burning oil, the combustion being more perfect than in burning coal, the heat generated in the fire box will be greater. Care should therefore be taken in setting the fire brick not to choke the passage between the upper portion of the arch and the crown sheet. If this area is insufficient, the products of combustion will impinge upon the crown sheet, and the intense heat generated at this point is liable to be detrimental to the sheet.

The forced draft occasioned by the exhaust should be so regulated as to be equally distributed through all the tubes. This can be accomplished by a careful adjustment of the "petticoat pipe" and deflecting plate. If a collection of soot appears on the sheet around some of the tubes, it will indicate that the draft through these tubes is not sufficient, and a readjustment of the draft rigging should be made until no such indications are perceptible. It is suggested that after the draft rigging in the smoke-box has been satisfactorily adjusted, it be rigidly attached to the boiler in such a manner as to be readily removed and replaced without liability of derangement.

As the weight of oil used by a locomotive for a given distance is about one-half the weight and bulk of coal for the same distance, it is obvious that a saving is made in the dead weight hauled, or with the same weight, fuel for a much longer

run may be carried. In locomotives without tenders it is often difficult to arrange for an adequate supply of coal without encroaching upon space required for other purposes. This difficulty is largely overcome when oil fuel is used, as the reservoirs can be located where it would be impracticable to place a coal bunker, and in this way room for a sufficient supply of fuel is easily obtained.

The tender tank of an oil-burning locomotive is usually constructed with two compartments, the upper being used as a reservoir for the oil and the lower for water. The partition which separates these compartments, and which forms the bottom of the oil reservoir is preferably inclined toward the front, to allow the oil to flow by gravity to the feed outlet. In cold climates a coil of steam pipe may be placed in the reservoir around this outlet, in order to rarefy the oil and insure an even and continuous flow.

ECONOMIC VALUE OF OIL AS FUEL.

"Fuel oil can be used in almost any form of firebox, the best location for the burner being just below the mud ring, spraying upward into the firebox. In some recent experiments with oil of eighty-four degrees gravity, 140 degrees flash and 190 degrees fire test, in which the boiler had twenty-seven square feet grate area and 2135 square feet of heating surface (eight per cent being in the firebox), it was found that there were about thirty-nine pounds of oil burned per square foot of grate area, and about .45 pounds per square foot of heating surface per hour, the equivalent evaporation from and at 212 degrees being about twelve and one-half pounds of water per pound of oil. It was also computed that there should be about one-third inch width of burner for each cubic foot of cylinder volume, or width of burner in inches equals:

$$\frac{\text{Volume of both cylinders in cubic feet}}{3}$$

or that one inch width of burner was sufficient for 600 square feet of heating surface.

"In the foregoing calculation, the figures are based on single expansion engines only. In compound locomotives the consumption of water will be ten per cent and the fuel about twenty per cent less than in single-expansion engines. By the above formula, in calculating the width of burner for compound engines, the volume of only the high-pressure cylinder or cylinders should be considered."*

* Report of Committee of American Railway Master Mechanics' Association, 1899.

To determine the value of oil, it is necessary to know the evaporative power of the boiler for each pound of fuel burned, which depends greatly upon the ratio of heating surface to grate surface, and the volume consumed in a given time. These conditions do not seem to affect the consumption of oil, the evaporation being about the same per pound of oil for all rates of combustion, it being impossible to consume the oil without a proper supply of air, and, as no smoke is made, no unconsumed fuel goes out of the stack, as is the case with soft coal. The following formula, based on experiments made by the Baldwin Locomotive Works, with a locomotive having compound cylinders, will give an approximate idea of the value of oil fuel as compared with coal:

$$\frac{\text{Cost of coal per ton} + \text{cost of handling (say 50 cents)} \times 10.7 \times 7}{2000 \times \text{evaporative power of coal}}$$

equals price per gallon at which oil will be the equivalent of coal.

It must be remembered in these computations that the cost of both oil and coal is considered at the place where they are delivered to the engine, and not at the place where they are purchased by the railroad company.

The following table gives the weight and volume of crude petroleum based on a specific gravity of .91, which is about the average of the Texas oil, as well as that received from South America:

WEIGHT AND VOLUME OF CRUDE PETROLEUM.

Pound.	U. S. Liquid, Gal.	Barrel.	Gross Ton.
1	.13158	.0031328	.0004464
7.6	.1.	.02381	.003393
319.2	42.	1.	.1425
2240.	294.72	7.017	1.

For convenience in obtaining correct approximate weights of petroleum oil, the following gravity conversion table can be used:

Degrees Baume.	Degrees Sp. Grav.	Lbs. in 1 Gal.	Degrees Baume.	Degrees Sp. Grav.	Lbs. in 1 Gal.	Degrees Baume.	Degrees Sp. Grav.	Lbs. in 1 Gal.
10	1.0000	8.33	32	8641	7.20	54	.7608	6.34
11	.9929	8.27	33	.8588	7.15	55	.7567	6.30
12	.9859	8.21	34	.8536	7.11	56	.7526	6.27
13	.9790	8.16	35	.8484	7.07	57	.7486	6.24
14	.9722	8.10	36	.8433	7.03	58	.7446	6.20
15	.9655	8.04	37	.8383	6.98	59	.7407	6.17
16	.9589	7.99	38	.8333	6.94	60	.7368	6.14
17	.9523	7 93	39	.8284	6.90	61	.7329	6.11
18	.9459	7.88	40	.8235	6.86	62	.7290	6.07
19	.9395	7.83	41	.8187	6.82	63	.7253	6.04
20	.9333	7.78	42	.8139	6.78	64	.7216	6.01
21	.9271	7.72	43	.8092	6.74	65	.7179	5.98
22	.9210	7.67	44	.8045	6.70	66	.7142	5.95
23	.9150	7.62	45	.8000	6.66	67	.7106	5.92
24	.9090	7.57	46	.7954	6.63	68	.7070	5.89
25	.9032	7.53	47	.7909	6.59	69	.7035	5.86
26	.8974	7.48	48	.7865	6.55	70	.7000	5.83
27	.8917	7.43	49	.7821	6.52	75	.6829	5.69
28	.8860	7.38	50	.7777	6.48	80	.6666	5.55
29	.8805	7.34	51	.7734	6.44	85	.6511	5.42
30	.8750	7.29	52	.7692	6.41	90	.6363	5.30
31	.8695	7.24	53	.7650	6.37	95	.6222	5.18

TABLE SHOWING RELATIVE HEAT PRODUCING POWER OF OIL AND COAL.*

	Pounds Oil.	Pounds Coal.
Theoretical Anthracite	1	1.61
Theoretical Bituminous	1	1.37
†Urquhart's Experiments	1	1.756
Peninsular Car Co. (1885)	1	1.742
Elevated R. R. New York (1887)	1	1.785

* Prepared by Dr. Charles B. Dudley, Chemist, Pennsylvania R. R. in 1888. In this table it is assumed that:

1 lb. Anthracite Coal contains 90 per cent carbon.
1 lb. Bituminous " " 85 " "
and 5 per cent hydrogen.
1 lb. Oil contains 86 per cent carbon and 14 per cent hydrogen.

The heat-producing power of the carbon and hydrogen is calculated by means of the well known heat units of these two substances.

† Thomas Urquhart, Locomotive Superintendent, Grazi-Tsaritzin Railway, Russia, was among the first to adapt locomotives to the use of oil. The use of solid fuel on this line was entirely abandoned in 1885. He designed a burner which was one of the first to utilize a jet of steam to atomize the oil as it enters the firebox. This method has been generally adopted in the construction of the most successful burners now in use.

TABLE SHOWING RELATIVE VALUE OF OIL AND COAL, FUEL ACCOUNT ALONE CONSIDERED.*

OIL PER BARREL AT	COAL PER TON AT
$0.20	$0.74
.30	1.12
.40	1.49
.50	1.86
.60	2.24
.70	2.61
.80	2.98
.90	3.35
1.00	3.73
1.10	4.10
1.20	4.47
1.30	4.85
1.40	5.22
1.50	5.59
1.60	5.97
1.70	6.34
1.80	6.71
1.90	7.08
2.00	7.45

* Prepared by Dr. Charles B. Dudley.

TABLE SHOWING RELATIVE VALUE OF OIL AND COAL, ALL ASCERTAINED ECONOMIES CONSIDERED.*

OIL PER BARREL AT	COAL PER TON AT
$0.20	$0.65
.30	.98
.40	1.30
.50	1.63
.60	1.96
.70	2.28
.80	2.61
.90	2.93
1.00	3.26
1.10	3.59
1.20	3.91
1.30	4.24
1.40	4.56
1.50	4.89
1.60	5.22
1.70	5.54
1.80	5.87
1.90	6.19
2.00	6.52

* Prepared by Dr. Charles B. Dudley.

TABLE SHOWING ADVANTAGES CLAIMED FOR OIL OVER COAL.

Reduction of waste fuel.
Economy in handling fuel.
Less weight of fuel to haul.
Fewer repairs to locomotives.
Economy in cleaning locomotives.
Less waste of steam at safety valve.
Economy in cleaning ballast.
Economy of space required for fuel.
Elimination of fires from sparks.
Elimination of smoke and cinders, adding to comfort of passengers.
Increased utilization of heat.
Can be lighted instantly.
Requires no stoking.
Can be regulated instantly and easily.
Makes no clinkers requiring frequent removal.
Engine can be turned quicker.
Makes no refuse or cinders to be handled.
Insures freer steaming and running, affording greater ability to handle maximum loads.

APPENDIX A.

DETAILED RULES ADOPTED BY THE SOUTHERN PACIFIC COMPANY, GOVERNING THE HANDLING OF OIL BURNING LOCOMOTIVES.

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1. WATER IN PAN.—All engines are provided with a sprinkler pipe to ash pan, which should in all cases be opened to carry off any oil drippings that reach the pan when starting the fire. This prevents combustion in the pan when the oil becomes heated. In case of crews or watchmen having to leave their engine for a short time, this precaution should also be taken.

2. STARTING FIRE.—Before starting fire, see that the bottom of the firebox, in front of the burner, is free from brick or any obstruction that would interfere with the free passage of oil from burner to front of firebox. Open blower strong enough to create necessary draft. Open atomizer valve long enough to blow water out of pipe; then close valve and light a piece of oily waste and throw it to center of firebox; then turn on atomizer strong enough to carry oil to fire. Open oil valve slowly until the oil ignites, using only enough oil to generate steam without making black smoke.

In firing up a cold engine the fire may go out; watch it closely until the engine is hot.

If at any time it should become necessary to fire up with wood, care should be taken that the brick work is not damaged.

3. PUTTING OUT FIRE.—First shut off the oil valve on tank; allow oil to be burned from pipe to burner, then close firing valve, atomizer and dampers. It is important that dampers should be closed to prevent passage of cold air through firebox and tubes when they are heated, after fire has been extinguished.

4. DRUMMING OF ENGINE.—Drumming of engines is caused by faulty construction of brick work in firebox; careless handling of oil valve by fireman when engine is working slowly, or by atomizer valve being opened too much.

Firemen on suburban trains should use the utmost care in handling oil valves and atomizers, with the view of avoiding disturbances of this character.

5. TEMPERATURE OF OIL.—To obtain the most economical results, the temperature of the oil in the tank should not exceed 100 degrees, as it is again heated in the super-heater. When oil in tender storage tanks is heated by direct steam, it is important that no more steam be admitted than absolutely necessary, as the condensation is liable to prevent continuous flow of oil to burner.

6. BLACK SMOKE.—Black smoke should at all times be avoided, and if in evidence, shows faulty construction of brick work or improper methods of handling. The soot formed by smoke is a non-conductor and will make an oil-burning engine fail in steam quicker than any other cause. An accurate combination of oil and steam in the atomizer, with the proper admission of air, is necessary to thorough combustion. To prevent smoke in starting and stopping, engineers should always notify the firemen when they are going to open or close a throttle.

CAUSES OF FAILURES AND HOW TO PREVENT THEM.

1. SMOKE WHICH STOPS UP THE FLUES WITH SOOT.—The firing valve should be opened gradually when engine is first started. Care should be taken to maintain the temperature of the firebox as nearly uniform as possible. The supply of oil should be gradually increased as the engine increases in speed, in accordance with the requirements of service. Do not force the firing. If the pressure falls back five or ten pounds, restore the maximum pressure by degrees.

Forced firing will fill the flues with soot, overheat the sheets, burn off rivet heads, and cause the boiler to leak.

2. IMPROPER SANDING.—The engine should be well sanded in going from roundhouse to train where practicable, again in pulling out, and several times the first mile or two. This is very important, as engines are more liable to be smoked up in starting the fire and around terminals than after starting. Keep on sanding as long as quantities of black smoke follow the act of sanding. If the supply of sand runs short, you may take it from the main sand box, or get it from cinder pot in front end and use it over again. Always hold the funnel in a position to carry the sand over instead of under the arch.

3. INSUFFICIENT FLOW OF OIL TO BURNER.—Burners are liable to clog up with sand, that is in the oil, or by pieces of waste sucked up by air inlet. A partial or complete stoppage of oil pipe or burner may be overcome by using the blow-back valve. To use this: Open tank valve, close firing valve, and open cock over super-heater. This will blow steam back through oil supply pipe; then close tank valve and open firing valve. This will blow steam through the oil pipe to burner. If the obstruction is not removed by doing this, the pipes will have to be disconnected or atomizer tube removed. Care should be taken to see that this blow-back valve is closed except when used for blowing out pipe and burner. If left open or leaking it will prevent free passage of oil to burner, thereby causing a series of explosions.

Sometimes a partial obstruction may be overcome by closing the air intake valve. This creates a partial vacuum in the burner. If oil flows out of intake pipe it is evident that the obstruction is in the burner.

4. WATER IN OIL.—In case the fire goes out from unknown causes, you should ascertain whether there is water in the oil by opening the drain cock.

Water accumulates in oil tanks sometimes by improper handling of heater. Opening it only a small amount and leaving it on continuously is bad practice. Put it on strong, heat the oil and shut it off. This should be done as much as possible when standing.

5. FALLEN BRICK ON BOTTOM OF FIREBOX OR STRIKING AN OBSTRUCTION, CAUSED BY AN ACCUMULATION OF ASPHALT.—An engine will not make steam well, and will cause an excessive amount of black smoke if the fire drags on bottom or strikes a fallen brick. Roundhouse men should inspect and clean pan under burner thoroughly; crews should inspect and keep it clean. If bricks fall, take them out or push them forward and remove the accumulation of asphalt and sand. The best time to do this is when the fire has just been partially shut off while at a station. Too much attention cannot be given to this point.

6. PARTIAL OR COMPLETE CLOSING OF ATOMIZER TUBE IN BURNER.—If the full opening of the atomizer valve will not remove obstruction, the tube must be taken out of burner. In most engines this can be done in from five to ten minutes.

7. SLIPPING OR WORKING ENGINE HARD WITH FIRE OUT.—Slipping or working the engine hard with the fire out, or starting before the fire is lighted, will cause the flues to leak immediately.

Great care should be exercised to prevent this.

Should it become necessary to do any work inside of the oil tanks after they are empty, first fill the tank with water, put in a few pounds of caustic soda, then turn on steam through the heater pipe until water boils over the manhole. Petroleum contains a greater or less per cent of volatile gases, which are given off at low temperature; therefore, under no circumstances should lighted torches, lamps or lanterns be taken into tanks or near the openings, that have contained crude oil, until they have been thoroughly cleansed.

DONT'S.

Do not leave the fire-door unfastened when starting fire, for, if too much oil is turned on, an explosion may occur, which will drive the flame out of the door, and might injure any one in the cab.

Do not use the blower at any time stronger than is necessary to clear the stack of black smoke, as it is a waste of fuel, makes an unnecessary noise, and, if the fire is burning lightly, will cause the flues to leak.

Do not start the engine without having the firing valve opened sufficiently to insure a good fire, so that the cold air may not be drawn through the flues by the exhaust.

Do not approach a manhole or vent hole in the tank with a lighted torch or lantern nearer than ten feet. To ascertain the amount of oil in the tank, use the stick or rod made for that purpose, carrying it to the light to find the number of inches of oil in the tank.

Do not allow the air cut off from fire by asphalt, sand or pieces of fallen brick accumulating in the pan; hoe it out.

Do not put fire out entirely at any time until engine is put in round-house by hostler.

In view of the fact that fuel oil will be used almost exclusively on many divisions in the near future, it is desirable that all concerned become thoroughly familiar with the apparatus pertaining to oil-burning locomotives, to the end that slight defects may be promptly remedied and success in its use assured.

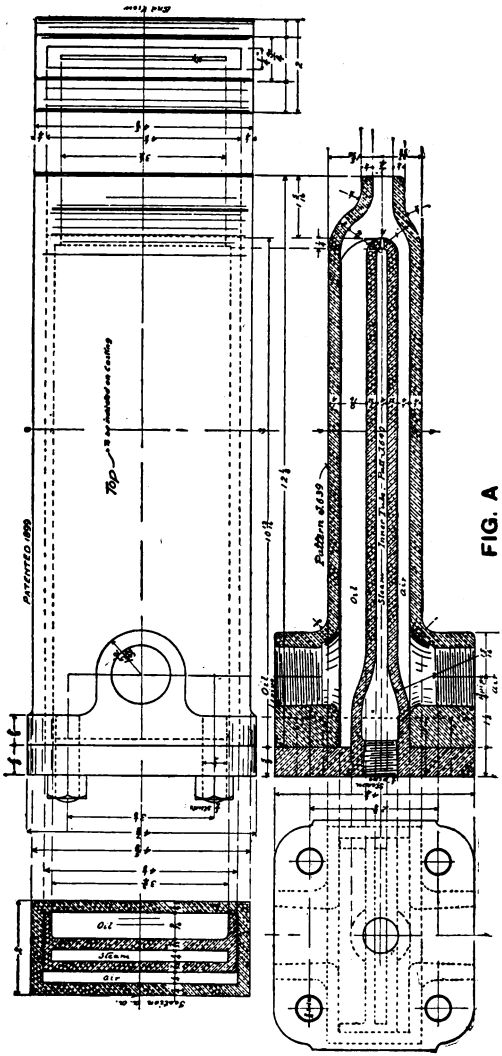


FIG. A

OIL BURNER — SOUTHERN PACIFIC.
(Three Sizes are used—2", 3" and 4".)

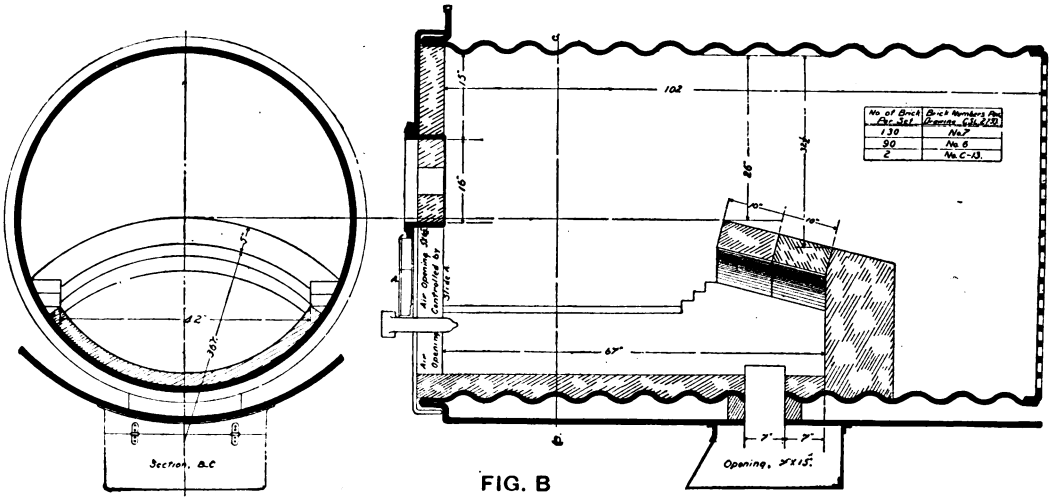


FIG. B

ARRANGEMENT OF BRICK WORK FOR OIL BURNING LOCOMOTIVES, CLASS E. F.- 1, (MOGULS WITH VANDERBILT CORRUGATED FURNACES,)—SOUTHERN PACIFIC.

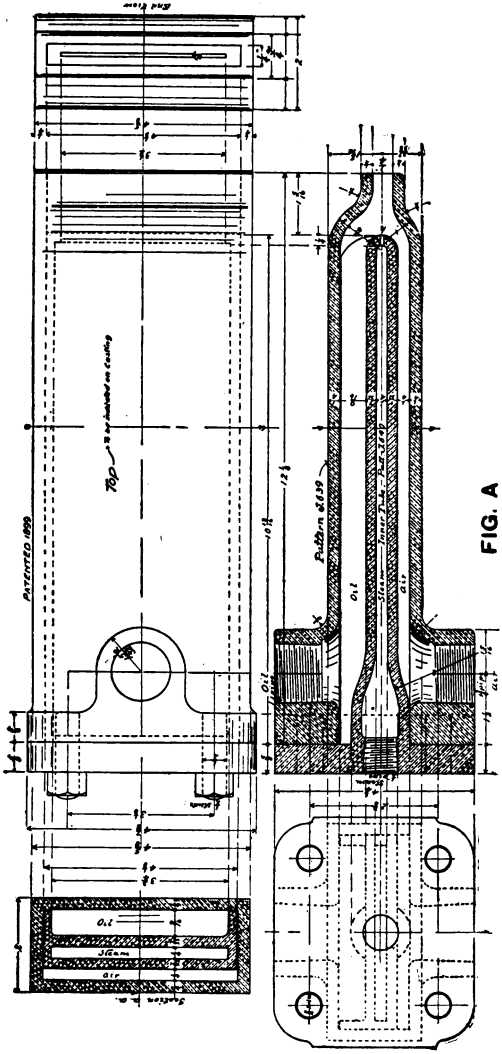


FIG. A

OIL BURNER — SOUTHERN PACIFIC.
(Three Sizes are used—2", 3" and 4".)

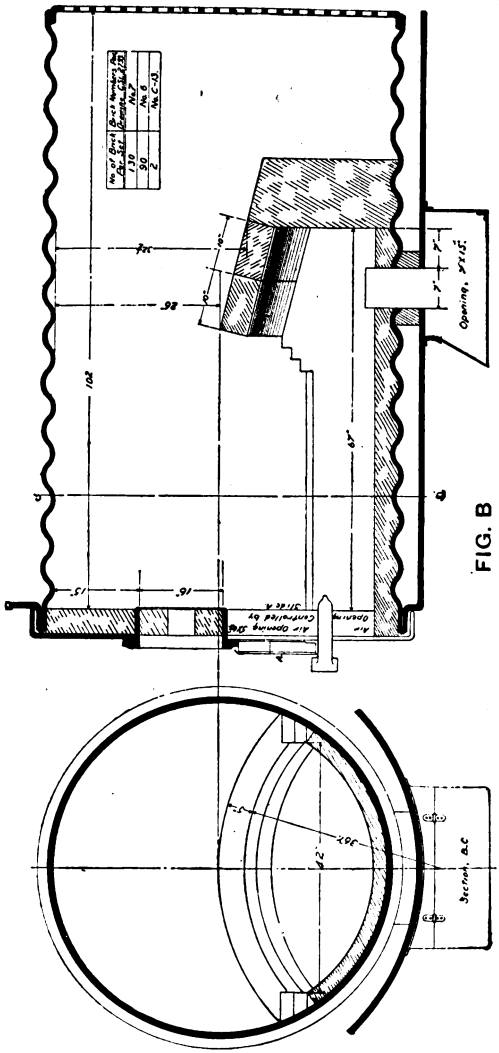
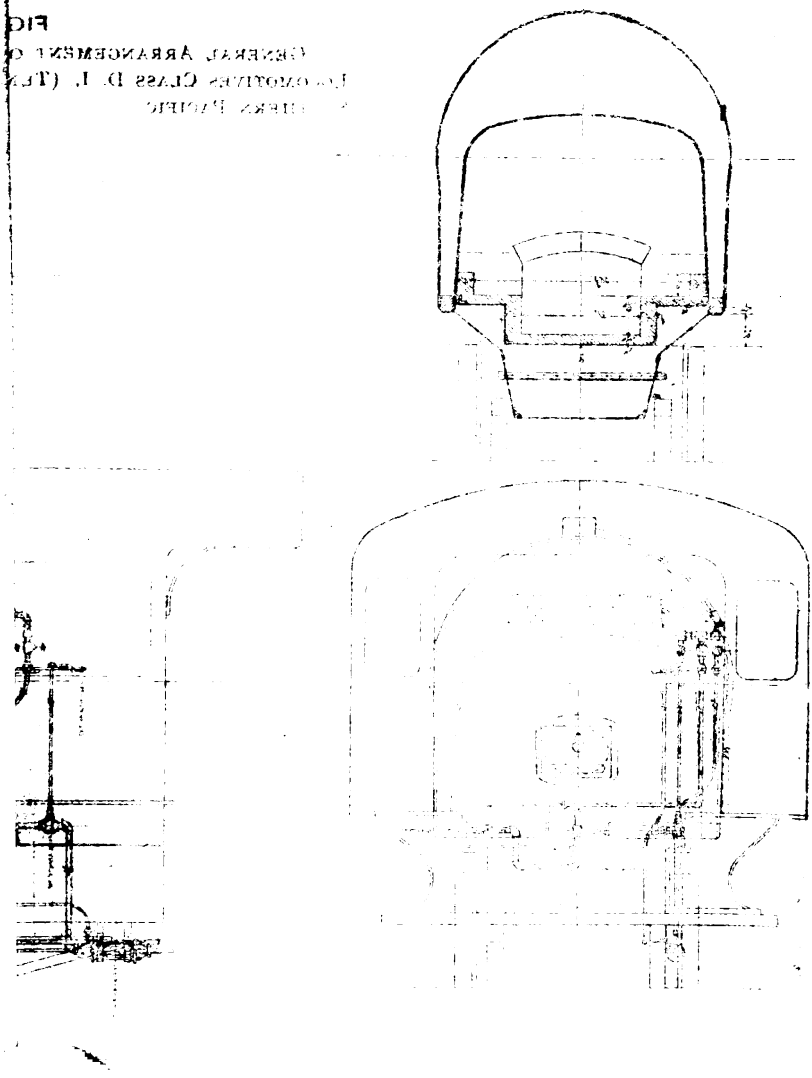
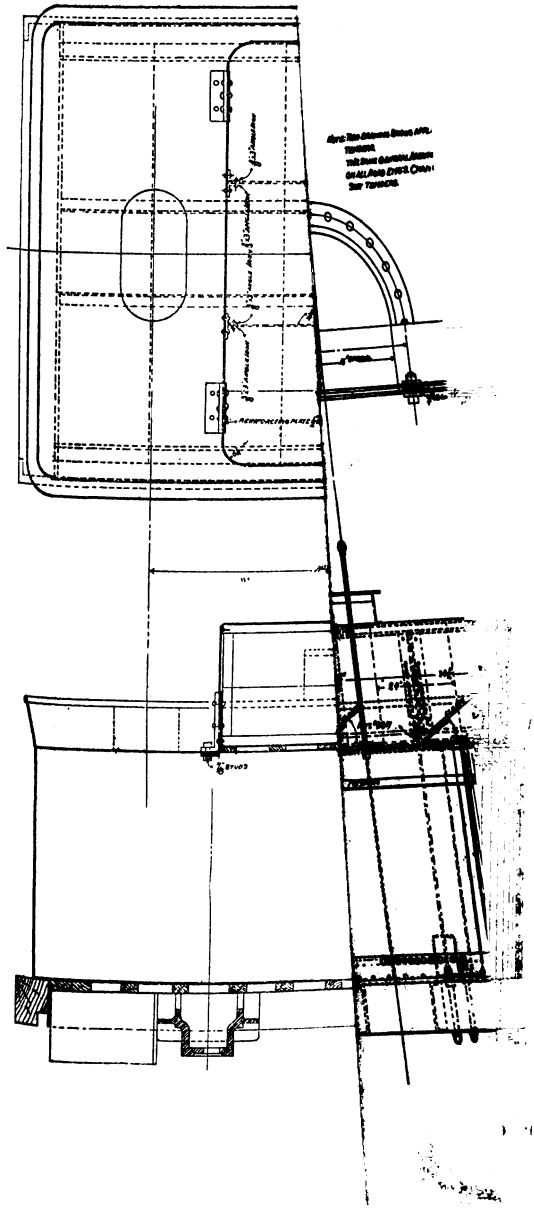


FIG. B

ARRANGEMENT OF BRICK WORK FOR OIL BURNING LOCOMOTIVES, CLASS E. F.-1, (MOGULS WITH VANDERBILT CORRUGATED FURNACES,)—SOUTHERN PACIFIC.





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